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A NOTE ON THE FORMATION OF THE ASSAM VALLEY.

P. H. CARPENTER, F.I.C., F.C.S. AND C. R. HARLER, B.SC., F.I.C.

GEOLOGY.

The geology of the Assam Valley as outlined in Memoirs of the Geological Survey of India* is of extreme interest and of great assistance in classifying the soils which lie about the flanks of the hills and on the plain of the Brahmaputra.

The Shillong Plateau which comprises the Garo Hills, the Khasia and Jaintia Hills and the Mikir Hills, may be taken as the starting point in the history of the Assam Valley. The core of this land mass is an ancient gneiss similar to that forming the Indian Peninsula. At one Period† in geological history the Shillong Plateau was at the head of a Southern Ocean of which the Bay of Bengal was a part, and India was joined to Africa on the west and Australia on the east. Later‡, the rock known as Cherra sandstone was deposited on the southern flank of the Khasia Hills.

To the north-west of the Plateau was one extremity of the Mediterranean Ocean of those days, which included a great part

* Geology of Darjeeling and Western Dooars, F. R. Mallet, Mem. Geo. Sur. of India, Vol. XI, pt. 1.

On the Coal Fields of the Naga Hills, F. R. Mallet, Mem. Geo. Sur. of India, Vol. XII, pt. 2.

Geology of Upper Assam, J. M. Maclaren, Mem. Geo. Sur. of India, Vol. XXXI, pt. 4.

The Petroleum Occurrences of Assam and Bengal, F. H. Pascoe, Mem. Geo. of India, Vol. XL. pt. 2.

The Geology of the Mikir Hills in Assam, F. H. Smith, Mem. Geo. Sur. of India, Vol. XXCIII, pt. 1.

† The End of the Jurassic Period.

‡ During the Cretaceous Period.

of the present Atlantic Ocean, most of what is now Europe, Tibet and the Himalayan region of Northern India. A great gulf of this ocean extended into what is now Sind and Cutch and up the Narbada Valley in the west.

Although the Southern Ocean extended into what we now call Upper Assam there was no direct connection between this and the Mediterranean Ocean but they were only separated by a narrow neck of intervening land somewhere in the neighbourhood of the Shillong Plateau.

At a certain period* changes took place in the earth's surface, a new era began, and the land formation began to take on the characteristics which prevail to-day. The next period† which saw the dawn of recent species, witnessed the sinking of much of the land in the Southern Ocean and the separation of India from Australia and Africa followed by the raising of the Tibetan Plateau and the upheaval of the Himalayas.

The history of the Shillong Plateau and the formation of the Brahmaputra Valley is based on geological evidence. Throughout most of the disturbance which took place the Plateau stood firmly, as is evidenced by the fact that overlying strata deposited by flooding, lie parallel to the bed rock and are not twisted and contorted as is the case with deposits made on the Himalayan slopes at various times. Unlike the Himalayas, the Shillong Plateau has been stable and quiescent throughout geological history.

To the east of the Shillong Plateau where we now have the Patkoi Range of which the Naga Hills are a part, the land was probably low lying and was later submerged and covered with thick deposits of mud and stones. Still later it was raised again and grew luxuriant vegetation which was again covered with mud during a later depression. This intermediate stage gave the coal measures of Assam, which have since been laid bare in the Margherita and Sibsagar districts and also on the southern flanks of the Mikir Hills.

* The end of the Cretaceous Period.

† The Eocene Period.

The next stage in the development of the Assam Valley was the rush of the waters of Tibet across what is now the Patkoi Range and Burma, with subsidiary outlets across part of the Shillong Plateau and into what is now Bengal. Thus thick deposits of gravel and silt were put down at the expense of the plateau which was rising in Tibet.

Throughout this period the Miju Range which now stands at the eastern extremity of the Assam Valley kept the general movement of water to the south and westward.

Now the Himalayas began to rise and at the same time the Patkoi Range also slowly appeared and the trend of the Assam Valley was definitely marked.

There is a break between the Shillong Plateau and the new Patkoi Range where the Jetinga Valley runs now and although the later deposits on the two ranges are similar, the ancient core of hard crystalline rock forming the older hills, outcrops throughout the Plateau.

The floor of the Assam Valley is probably the type of rock called gneiss found in the Shillong Plateau and Peninsula India. This gneiss appears in many places more or less remote from the main range, notably at Silghat, quite close to the Mikirs, at Bishnath and at Tezpur. In Goalpara again, near Sorbhog, small hills detached from the Garo Hills appear and even near the Himalayas up the Raidak River in the Eastern Dooars evidences of the old gneiss are found*.

Above the massive gneiss composing the core of the Mikir Hills there lies the recent sedimentary rocks telling the history of the various periods of inundation and flooding which has occurred in later geological times. Most of the geological inves-

* The rock from the hill on which the Tezpur Chummery stands is a biotite-granite, crushed in parts. The rock from Tezpur quarry is a fine grained hornblende-biotite-granite with a little sphene.

The rock from Silghat is a fine grained biotite-granite, slightly gneissose in structure.

In the Raidak River a hornblende schist occurs.

tigations have been carried out from the economic point of view and hence have been generally made in the South Mikir Hills where the Sibsagar coal strata continue, but only in thin veins which would not pay to work. The Tertiary rocks (the later deposits) correspond naturally with those of the Naga Hills on the other sides of the Dhunsiri Valley and includes the Desang, the coal measures, the Tipam and Dehing groups, named in order of their deposition.

The Alluvium of the Assam Valley.

As was mentioned above, the floor of the Assam Valley is probably the gneiss which composes the Shillong Plateau. This is overlaid with a great thickness of alluvium put down in recent geological times and it is on these deposits that most of the tea gardens are put out.

Round the southern slopes of the Himalayas there is a fringe of foot hills known as the Siwalik Range. These hills are composed of the alluvial detritus of the mountains, swept down by rivers and deposited at their feet and consolidated later. This chain of sandstone hills continues round the Assam Valley, and then between the Shillong Plateau and the Naga Hills and on to South Sylhet where it appears in the red sandy hillocks. In the Dooars the local name for these deposits is the Nahan series, and in Assam, the Tipam series. In one or two places there are notable breaks in the Tipam sandstone. Thus at the head of the Valley the ancient rock of the Miju Range abuts on to the recent alluvium. At Margherita and Nazira the Tipam sandstone has been washed away exposing the coal measures of an earlier age. Naturally much geological work has been carried out in this district and it was from Tipam, a village near Jaipur, that the local name given to this series of sandstones was derived.

With the rise of the eastern Himalayas and the contemporaneous uplift of the Patkoi Range, the detritus from the streams of the Tibetan Plateau was naturally laid down in the

newly formed Assam Valley. This deposit is spoken of as old alluvium.

With the subsequent sinking of the Brahmaputra Valley another great wash-out occurred and the alluvium filling the Valley was mostly washed away or covered with a fresh deposit which we call new alluvium. This alluvium now generally forms a red loam which may be seen to-day on the Red Bank of the Dooars, the Bishnath Red Bank and in various places along the foothills, overlying the Tipam ranges. In many places, *e.g.*, Nazira, the Golaghat district, the Nowgong district, Tezpur, the old alluvium just appears through the new alluvium. On these outcrops many of the tea gardens are put out and in fact in many districts the position of a tea garden means an outcrop of this older soil.

Some geologists consider that only these outcrops which really stand high above the plain like the hills at the back of Singlijan in the Boroi district and parts of the Bishnath Bank should be considered as old alluvium. The low outcrops are designated merely as ' bhangar ' or high land as opposed to ' khadar ' or low land subject to flooding. Other geologists consider that these low lying outcrops are so cut up by the network of streams and often so mixed with newer deposits that it is impossible to say whether the soil is a true old alluvium or an older new alluvium.

SOIL SURVEY NOTES.

The Dhunsiri and Nowgong Districts.

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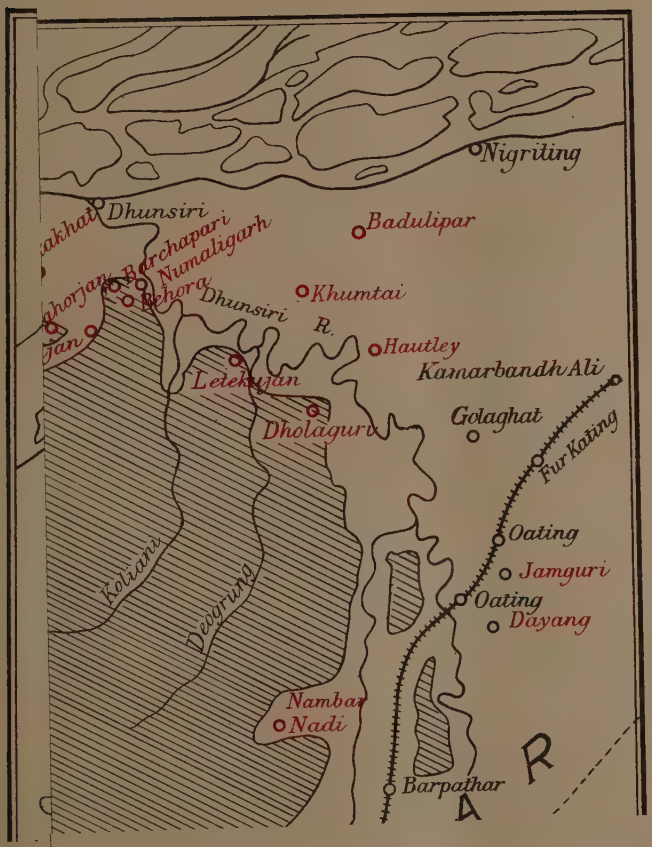
Geography.

From a scientific point of view it is unsound to consider the Dhunsiri and Nowgong districts apart from the western end of the Golaghat district. The study of these three areas includes all the gardens put out on the slopes of the Mikir Hills. Whilst however the gardens of the first two districts are practically all confined to the hill slopes, those of the Golaghat area extend for some miles from the hills and are planted on the outcrops of red soil which resembles that occurring near the hills. It will thus be seen that for convenience the Golaghat district is best considered as a whole rather than in part with the Dhunsiri and Nowgong areas.

The Mikir Hills occupy a tract of country between Nowgong and Golaghat. To the north they run very near the Brahmaputra flood plain and it is along this face that the Dhunsiri gardens are put out. To the west they present a series of bays and detached hillocks which gradually disappear into the new alluvium of Nowgong. The tea gardens are planted in these bays and on the hillocks near the main range. To the southward they are separated from the Jaintia Hills by the Kopili River and from the Naga Hills by the upper part of the Dhunsiri Valley which is occupied by the Nambor forest. On these flanks of the hills there are no tea gardens because of the rain shortage. To the east the hills tail off gradually into the Golaghat district. The Dhunsiri may be taken roughly as their limit in this direction.

The Jamuna River cuts the hills into two portions known as the North Mikir or Rengmas and the South Mikirs. The northern hills form the higher section of the group and reach a height


Nigriting
Dhunsiri
Badulipar
Numaligarh
Khumtai
Dhunsiri
R.
Hautley
Kamarbandh Ali
Golaghat
Dholaguri
Oating
Jamguri
Oating
Dayang
Nambar
Nadi
Barpathar
A
R

of 4,000 feet in places. The southern hills rarely touch 1,500 feet in height.

Rainfall.

An examination of the rainfall records of the various gardens round the Mikirs is instructive.

The figures for the three districts are as follows and most values represent the average over the past 15 years :—

Nowgong.		Dhunsiri		W. Golaghat	
Kondoli	... 64 ins.	Hathikuli	... 69 ins. (3 yrs.)	Letekujan	... 73 ins.
Rangamatti	... 84 ,,	Methoni	... 82 ins.	Dologuri	... 79 ,,
Deejoo Valley	... 96 ,,	Diphlu	... 82 ,,	Hautley	... 73 ,,
Lengteng	... 82 ,,	Nahorjan	... 84 ,,	Doyang	... 70 ,,
Salonah	... 83 ,,	Bokakhat	... 83 ,,	Jamguri	... 61 ,,
Amluckie	... 76 ,,	Borsapori	... 85 ,,	Nambarnuddi	... 50 ,,
Kellyden	... 80 ,,	Numaligarh	... 82 ,,	Khumtai	... 78 ,,
Seconee	... 84 ,,			Badulipar	... 83 ,,
Silghat	... 70 ,,			Tocklai	... 83 ,,
Kuturi	... 81 ,,				

In Nowgong, the rainfall is, on the whole, the heaviest of the three divisions. Here the hills stand up to meet the first onslaught of the Monsoon as it advances from the west round the Garo Hills, past the Khasia Hills and then across the wide stretch of flat land between Gauhati and Nowgong. Kondoli at the southern end of the district comes somewhat within the rain shadow of the Khasia Hills and has a rainfall of 60 inches only. Not far from this garden (30 miles) but on the eastern side of the spur is the Lumding plain which is a bay almost entirely surrounded by hills so that only 30 inches of rain are deposited.

Of the other gardens considered in this district, Amluckie showing the lowest rainfall, 76 inches, is furthest from the hills. Deejoo Valley which is the wettest garden with 96 inches, is situated in a bay in the hills, the mouth of which faces the advance of the Monsoon. Koliabur is situated at Silghat on a low hill (780 feet) isolated by 6 miles from the main hills and its rainfall is lower than would be expected. Kuturi, although still actually in the Nowgong district, is on the northern slopes of the hills.

The distribution of rainfall in Nowgong is poor and early droughts are common.

In the Dhunsiri district the distribution is somewhat better than in Nowgong. The low value for Hathikuli (69 inches) is surprising although the situation of the rain gauge may account in part for the low figure. Only three years' records are available. Hathikuli is a garden put out on a narrow shelf about half a mile wide, between the hills which rise precipitously, and the Kaziranga Bheel. The bheel is about 40 feet below the garden and it is on this bank the rain gauge is placed. The rain sweeps along the hills and although the actual fall in the garden may be only about 70 inches the effective fall due to seepage must be much greater. Methoni and Bokakhat, the other two gardens on the bheel edge are not so near the hills.

At the western end of the Golaghat district we enter the rain shadow of the Mikirs and although the clouds seems to work up the Dhunsiri River which here runs along the hills, the Jamuguri rainfall is 20 inches behind Numaligarh and 10 inches behind Letekujan. Nambarnuddi is still worse off with 50 inches.

The rainfalls of Khumtai, Badulipar and Tocklai are given to illustrate the decreasing influence of the hills as the distance from them increases. In addition to a general increase in rainfall as we proceed up the Assam Valley the distribution improves, for additional rain bearing air currents are now met, and clouds which may pass western districts encircle the eastern end of the valley till precipitation occurs.

Laterisation and Sedimentation.

During the process of sedimentation the mechanical type of soil laid down will depend chiefly on the slope of the land, which in turn influences the rate of flow of the water. From a quickly flowing stream sand will be the chief deposit; from still water clay is deposited. Unless the slope of the land is less than six inches to the mile, silt will be carried on and coarser particles mainly laid down.

After a soil has been once put down the process of weathering begins to take place. Now weathering is chiefly a chemical process which attacks soil particles rendering certain portions soluble. This leads to the breaking down of the particles, and to a change in the composition of the soil because the soluble portions are removed by water. The weathering of a rock depends on three main factors, *viz.*—the original composition of the rock, the amount of rainfall to which the rock is subjected and the temperature. If, owing to the heavy rainfall, more water percolates through the soil than leaves it by evaporation, then the tendency will be for the soluble constituents of the soil to be washed away. This is what happens in Assam. In England, where the rainfall is light, the general tendency is, for water to move upwards in a soil by virtue of surface evaporation and there is a constant fresh supply of soluble soil constituents being brought to the surface.

Thus the same soil in England and India would be expected to weather to quite a different product. The table below shows what has been observed.*

	Dolerite from India.	Laterite formed from it.	Dolerite from England.	Clay formed from it.
Silica	50·4	0·7	49·3	47·0
Phosphoric acid	...	...	0·2	0·7
Aluminium oxide	22·2	50·5	17·4	18·5
Iron oxide	13·5	23·4	11·0	14·6
Calcium oxide (Lime)	8·4	...	8·7	1·5
Potash	1·8	...	1·8	2·5
Soda	0·9	...	4·0	0·3
Water	0·9	25·0	2·9	7·2

The rock particles consist of compounds made up of the oxides of aluminium and iron combined with silica, together with certain bases which become soluble when broken down by weathering.

In England, the weathering process, roughly speaking, removes the soluble bases leaving silica combined with the oxides of iron and aluminium, which compound is clay.

* Hope—Certain Aspects of Tea Industry in Java and Sumatra, p. 31.

In tropical countries the decomposition goes further. In the course of ages the compounds of aluminium and iron with silica are also largely decomposed. The silica is washed away leaving a rock or soil containing a high percentage of the oxides of aluminium and iron. These rocks are known as laterites and the soils derived therefrom are called lateritic soils. The oxide of iron gives the well known red colour to laterite. Although laterites contain large percentages of fine particles of clay size, lateritic soils are often open grained because during laterisation most of the sticky, colloidal constituent of clay, *i.e.*, the soluble silica, has been washed out.

In England only small quantities of soil constituents are washed out, chiefly the lime, and the soil on the whole remains the same chemically but the physical state changes and a light soil is weathered to a heavy one.

It will be understood that the " banks " which crop out in Assam are merely alluvial deposits which have had time to weather although originally they were similar to the new alluvium. It has been noticed that with cultivation a soil may weather within a few years, judging by the red colour which it takes on. One method of classifying our soils then, is according to their age. Generally speaking, the redder the soil, the greater its age although the degree of weathering and the resulting redness must depend on the exposure.

From the chemical point of view we may look for certain indications of age in a soil. Thus a new soil will be white or grey whilst an old soil will be red by virtue of its greater iron oxide content. A new soil is often poor in organic matter because it has not had time to collect humus whilst the greater age of a red soil has given time for humus to accumulate. Much humus darkens a red soil so that in order to gauge the true colour of an area it is sometimes necessary to examine the subsoil. The acidity of a soil is some measure of its age. An old soil has had most of the soluble bases leached out and hence has a low lime content and a consequent high acidity whereas a new soil usually displays exactly opposite characteristics.

The points may be summarised as follows :—

An Old Soil.	A New Soil.
reddish in colour	white or grey in colour
rich in organic matter	poor in organic matter
high acidity	low acidity
low lime	high lime.

Specific examples are given below although it must be borne in mind that analyses do not always run in this direction.

	Borsapori. red soil.	Bokakhat. patch of new grey soil.
Organic matter ...	4.63 %	3.16 %
Acidity ...	2,713	517
Available lime ...	0.020 %	0.047 %

From the mechanical analysis of a soil much can be gleaned regarding its age and formation. In order to express briefly the constitution of a soil from the physical point of view the following nomenclature for denoting soil fractions has been suggested.*

The five fractions :—

Coarse sand
Fine sand
Silt
Fine silt
Clay

are denoted by the numbers—1, 2, 3, 4, 5 respectively and a soil is designated by these five figures placed in order according to the percentage of each fraction as it occurs in a soil. Two examples will suffice to illustrate.

Fraction No.	Fraction.	%.	%.
1	Coarse sand	40	15
2	Fine sand	30	5
3	Silt	10	10
4	Fine Silt	5	30
5	Clay	15	40
	Type ...	1, 2, 5, 3, 4	5, 4, 1, 3, 2

* Hope and Carpenter—Suggestions for the Manurial Treatment of Soils.

With ordinary sedimentation we get the coarser particles predominating when the water is flowing fast in the upper reaches of a river whilst as the current slows up, the finer particles fall. Theoretically the soil laid down by a fast flowing river would be of the type—

1, 2, 3, 4, 5

with the coarse sand fraction (No. 1) predominating and only a minute quantity of clay (No. 5) which would have been carried down by the other particles and would not have settled of its own accord.

As the current slows up and most of the coarse sand is left behind the type would change for a short time to 2, 1, 3, 4, 5 (the fine sand predominating) but the coarse sand would soon drop out all together.

Gradually the finer fractions come to the fore and important stages in the change would be the type :—

2, 3, 4, 5, 1
3, 4, 5, 2, 1
4, 5, 3, 2, 1
5, 4, 3, 2, 1

with the sand fractions (Nos. 1 and 2) negligible quantities in the last three types. The type 5, 4, 3, 2, 1 would only be deposited from standing water.

A point of interest is that in sedimentary soils, coarse and fine particles do not occur together as the major fractions and even when they occur together as minor fractions one is usually much greater than the other. Sand is laid down by a fairly fast stream and clay from still water. Hence if these two fractions appear together in considerable quantities it may be assumed that the sand has weathered to clay and hence the soil is an old one.

Soils showing major fractions of the type—

1, 2, 5
2, 1, 5
5, 1, 2
5, 2, 1

are soils which have been formed *in situ* from the rocks on which they lie, or soils which have weathered. Many red soils which might be expected to show analyses of these types fail to do so and the only conclusion is that they are not so old as they appear, or that the original deposit contained a high percentage of quartz grains which are not decomposed by weathering. Soils in the Sibsagar district show this characteristic.

The only soil in the Dhunsiri district which definitely shows the clay and sand as major fractions is one from Delamara, an out-garden of Methoni, put out in the hills. Here the type is—

2, 5, 4, 3, 1

with 27 per cent. of fine sand and 26 per cent. clay, although as is mentioned later this constitution may be due to surface washing of clay from higher levels.

On the Red Bank of the Dooars which is old alluvium the 5, 1 and 1, 5 types are common. At Dholbagan in the Nazira district the type—

2, 5, 1, 4, 3

with 23 per cent. of both fine sand and clay, has been met on a bank of old soil. The three types—

1, 2, 5, 3, 4
2, 1, 5, 3, 4
1, 5, 2, 3, 4

are common on the South Sylhet *teelas* which are definitely old and hence much weathered soils.

Although the red soils of Dhunsiri and Nowgong only occasionally show the characteristic grouping of a weathered soil commencing with 1, 5, or 2, 5, still the clay fraction (No. 5) seldom comes last in the type chain and practically always exceeds the coarse sand fraction. Thus the types :—

3, 2, 4, 5, 1
2, 3, 4, 5, 1

occur in Numaligarh, Borsapori and Behora with the clay fraction amounting to about 10 per cent. each. Such a soil would

hardly be expected to result from a simple sedimentation but would be made possible by weathering.

On the grey sandy soils which are definitely new alluvium the clay fraction is almost invariably the smallest.

The Dhunsiri District.

The Dunsiri district consists of a narrow strip of country about 27 miles long, between the northern slopes of the Mikirs and the flood plain of the Brahmaputra. To the east the district is bounded by the Dhunsiri River which finds its way circuitously to the Brahmaputra and then cuts into the south bank of that river to form a *suti*. Very old maps show the Dhunsiri as being the same river as the Kalang which now runs from Kalangmukh, above Silghat, as a *suti* of the main stream, through Nowgong to a point some miles above Gauhati. It is probable that when the Brahmaputra made its southward sweep from Gamirighat, it cut off the loop of the Dhunsiri as it then flowed on its way to Gauhati. Atlhough the Brahmaputra oscillates within certain limits, the general tendency of the river is to move to the south owing to the greater amount of tributary waters flowing in from the north side.

Throughout the Dhunsiri district red soil is found and even on gardens like Bokakhat which are on new alluvium, shallow trenches often show the older red soil.

The three gardens Numaligarh, Behora and Borsapori stand on a red bank which is separated from the main mass of the Mikir Hills by a stretch of low lying land. This area is cut up by hullahs and many of the soils from the slopes and lower parts of the gardens thus vary from the general type which is a medium soil containing fine sand or silt as the principle fraction and from 10 per cent. to 15 per cent. clay.

At Numaligarh we have the types—

2, 1, 3, 4, 5
2, 3, 4, 5, 1
3, 2, 4, 5, 1 (2 examples).
3, 4, 2, 5, 1
5, 2, 4, 3, 1.

In four cases the type ends with the 5, 1 combination with the clay (No. 5) about 10 per cent. The last case, which is not typical of the garden, shows a clay content of 31 per cent.

At Behora the soils are on the whole much stiffer. The following types occur—

2, 3, 4, 5, 1
2, 5, 3, 4, 1
2, 5, 4, 3, 1
3, 2, 4, 5, 1
3, 4, 2, 5, 1 (2 examples).
4, 5, 3, 2, 1
5, 2, 3, 4, 1
5, 4, 3, 2, 1 (subsoil).

The clay is as low as 10 per cent. in one case only, the 3, 4, 2, 5, 1 sample. In the other samples it is about 20 per cent. whilst in the last example but one it runs up to 51 per cent. In the subsoil the clay is 29 per cent.

At Borsapori several types occur—

3, 4, 5, 2, 1 (2 examples).

These are stiffish red soils containing about 18 per cent. clay and only a small coarse sand content. The types—

2, 3, 4, 5, 1 (3 examples).
3, 2, 4, 5, 1

occur. These again contain about 15 per cent. clay.

The heaviest type met on this garden is—

2, 3, 5, 4, 1

with each of the fractions fine sand, silt and clay about 26 per cent. whilst the fine silt and coarse sand are about 9 per cent.

The red soil occurring in these three gardens require much more careful treatment than the lighter soils of the district. In addition, the subsoil is either very stiff or toxic, for the root development of the bushes leaves much to be desired and on this account the drought is badly felt. In such gardens the conservation of soil moisture is the foremost problem.

A foot or so down, the soil becomes very red and nodular and is of the type which coolies, especially the women, like to eat.

At Lukajan, the out-garden of Borsapori, the lie of the land is different and the soil appears to be a new one. It is dark in colour and resembles in look and texture that found to the south of Numaligarh where the land tends to slope towards the depression which separates the gardens from the hills proper. No analyses of this part of Numaligarh are available.

The sample from Lukajan is of the type—

4, 3, 5, 2, 1

with 24 per cent. of clay and practically no coarse sand. The organic content of the soil is high and this, combined with the good tilth tends to make the soil seem lighter than its analysis would suggest. The tea does well on this garden.

The soil is black and is probably a new one either deposited by the Brahmaputra as it quietly backed up here in the past or, more likely, it was laid down by washing from the hill slopes. The type of light grassy jungle which occurs here would tend to stop much of the clay as it was being washed down such a gentle slope.

Bokakhat is placed on the edge of the flood plain. From the tea a sharp drop of 20 feet is made to the actual plain and within recent years this bank was probably laved by the main stream. From the edge of the bank the course of the Mora Dhunsiri can be followed by means of the trees. Still further away can be seen the Brahmaputra banks marked by a line of Simul. In the dry season the bheel is still moist and as the water recedes the *ryot* follows its retreat with mustard crops.

The tea at Bokakhat has good root development and does not feel the drought badly. It is said that on this garden the green fly is perpetually active in sufficient numbers to affect the quality of the tea.

At Bokakhat although all the soils are light sands there are two kinds of such soil, one growing tea well and the other badly.

The poor soils show a much lower acidity than the good ones, suggesting that they are of much more recent origin. To support this idea it may be noted that the poorer soils are near the edge of the bank.

Another interesting soil is that from an old *busti* site on which tea refuses to grow. Mechanically this soil resembles the others but chemically it is rich in lime and phosphates and low in acidity. In tilth it is poor. The best use for such soils is to put them under semi-permanent green crops and to use such areas as reservoirs for green stuff for trenches.

The following types occur—

1, 2, 3, 4, 5
2, 1, 3, 4, 5 (3 examples).
2, 1, 3, 4, 5 (subsoil).
2, 1, 4, 3, 5
2, 3, 1, 4, 5
2, 3, 4, 1, 5
2, 4, 3, 1, 5.

In every case except one the clay is the smallest fraction, generally about 10 per cent. In the case of the subsoil of the type 2, 1, 5, 4, 3 the clay fraction is only slightly greater than the fine silt and silt.

Nahorjan, including Tipujan and Balijan, is put out at the end of a spur which runs out from the Diphlu valley. There are several types of soil, varying from the heavier red found on the hills slopes to the coarser grained newer soils.

On Nahorjan itself the types—

2, 3, 4, 1, 5
2, 1, 3, 4, 5

occur. They are both light soils containing only a small percentage of clay. The second example is a gravelly soil supporting fine tea.

At Balijan the type—

2, 3, 4, 5, 1

is met. This is another light soil growing good tea. The clay fraction is only 5 per cent. whilst the fine sand amounts to 47 per cent.

At Tipujan the types :—

2, 3, 4, 1, 5
2, 3, 4, 5, 1

occur. The coarse sand and clay fractions are about equal in both cases and approximate to 7 per cent. In both cases the fine sand is about 40 per cent., and silt about 25 per cent. and the fine silt 15 per cent., yet the first soil is blackish and the other one red. Both soils grow tea well.

Diphlu which includes Old Diphlu, New Diphlu, and Latabari stretches from the hills down to the Brahmaputra flood plain. Old Diphlu is put out on a series of small hills and the soil is red and deep, supporting good tea with well developed roots. The southern slopes of the hills suffer from sun exposure. Unfortunately no analyses of the soil of this part of the garden are available.

At New Diphlu lower down the slope the type—

2, 3, 4, 5, 1

occurs in both the areas examined. The clay in each case is 9 per cent. and the coarse sand 7 per cent. At a few feet down the red soil appears.

At Latabari which runs down almost to the flood plain two samples both showed the type—

2, 1, 3, 4, 5

which points definitely to a new soil. Here the red soil is only met at a considerable depth.

On these lighter soils the tea, when once established, does extremely well and owing to the generous root development the bushes are able to withstand droughts.

Methoni was first put on the Kaziranga Bheel but this area was abandoned. The garden is now planted on the edge of the bank which runs along the bheel.

At Methoni the type—

2, 3, 4, 1, 5

occurs and at Silguri an out-garden similarly situated the slight variant—

2, 4, 3, 1, 5

occurs. In both cases the fine sand amounts to about 50 per cent. and the clay is below 10 per cent.

As soon as the bank on which Methoni is planted is left, and we descend to the flood plain, the soil from the rice field is found to change abruptly to a heavy clay of the type—

4, 5, 3, 2, 1.

One explanation of this sudden change is that at some period after the sandy bank was laid down and the main stream left this part of its course, water quietly backed up into this area at a time of exceptional flood and deposited a layer of clay.

At Delamara, another out-garden situated in the Diphlu valley a few miles in the hills, some interesting types were observed. The garden is put out partly on a gentle slope which goes down to a stream. The soils at the top and bottom of the slope give the following analyses :—

	Top of slope	Bottom of slope.
Coarse sand	4	4
Fine sand	42	27
Silt	21	17
Fine silt	16	18
Clay	10	25
Type ...	2, 3, 4, 5, 1	2, 5, 4, 3, 1

This appears to be a case of surface washing resulting in the removal of the clay from the top to the bottom of the hill.

The soil is red throughout and supports fine tea, indeed this spot seems ideal for tea growth both from the soil and climatic point of view. With cultivation however the soil will eventually become hard like other red soils of the district, unless organic matter is constantly added.

Hathikuli, like Methoni, is on the sandy ledge between the hills and the Kaziranga Bheel. The garden occupies a fairly long strip of land. At one end of this strip, Rangajan, the types—

2, 3, 4, 1, 5
2, 1, 3, 4, 5

occur, and on the main garden the type—

2, 3, 4, 1, 5

occurs. These are all new soils. Although much of the tea on the garden is old now, the soil is capable of supporting vigorous bushes when they are once established.

It is particularly noticeable that at the immediate foot of the hills there is a slight depression where the soil is gravelly and the vegetation suddenly changes till the heavier soil of the hills themselves is encountered. With greater hill ranges, this depression and gravelly band is naturally magnified, giving rise to a very definite break between the plains vegetation and that of the hills.

It is worthy of remark that the sandy soils of the Dhunsiri district are not nearly so sandy as those on the opposite side of the Brahmaputra in the Bishnath district. Many of the Dhunsiri sands contain about 10 per cent. clay, a figure seldom shown by the Bishnath sands.

The Treatment of Dhunsiri Soils.

Few full analyses of soils of the Dhunsiri district, including both chemical and mechanical analyses, are available. The fol-

lowing table shows analyses of both red (Numaligarh, Borsapori and Behora) and grey soils (Bokakhat).

SOILS OF THE DHUNSIRI DISTRICT.

	Numaligarh.	Borsapori.	Behora.	Bokakhat typical soil.	Bokakhat new patch.
MECHANICAL ANALYSES.	%	%	%	%	%
Coarse sand... ...	2	13	12	34	26
Fine sand	23	27	24	33	35
Silt	31	22	19	9	10
Fine silt	22	18	15	8	11
Clay	11	15	2	7	9
Loss on ignition (total organic matter) ...	5·2	3·53	4·47	3·79	3·17
Soil Type	3, 2, 4, 5, 1	2, 3, 4, 5, 1	2, 5, 3, 4, 1	1, 2, 3, 4, 5	2, 1, 4, 3, 5
CHEMICAL ANALYSES.	%	%	%	%	%
Soluble Humus (Grandeau)	2·84	1·81	1·81	1·39	1·06
Acidity (Veitch-Albert) ...	1890	1308	1673	1527	517
Total Nitrogen ...	0·086	0·102	0·078	0·045	0·075
Available Potash ...	0·023	0·006	0·007	0·018	0·010
„ Phosphates ...	0·004	0·025	0·020	0·017	0·007
„ Lime ...	0·024	0·028	0·022	0·039	0·047

The red soils are seen to be only moderately well supplied with organic matter and to be poor in nitrogen. The typical soil of Bokakhat, although it is a new light soil, is well supplied with organic matter and is very acid for such a light soil. In judging the food supply of a soil the mechanical analysis must be taken into account, for the root range in a light soil is usually so much greater than that in a heavy soil that a smaller percentage of food suffices to support the bush. The Bokakhat soil, like the older ones, is deficient in nitrogen. The new patch of soil from Bokakhat is much poorer than the typical soil in organic matter both total and available (Grandeau) and the acidity is only about a third of that shown by the normal soil of this garden.

So far as manuring experiments go in the Dhunsiri district it has been found that the red soils respond well to nitrogen,

which would be expected from their deficiency in this food. As is usual on heavy soils, sulphate of ammonia does well, which is fortunate owing to the fact that this is the cheapest nitrogenous manure in the market at present.

Oilcake is also a good nitrogenous manure giving results later than sulphate of ammonia but if used over a period of years it builds up a very satisfactory and gradually increasing fertility.

The factor having most influence on fertility is the organic content of the soil, which must be maintained, otherwise a garden will surely deteriorate. Certainly chemical manures supply food but they do not put new life into the soil as do organic manures. Many of the difficulties which appear after the annual drought would not arise if a sufficient quantity of organic matter, especially cattle manure, were available.

Liming on both heavy and light soils has not shown good results so far as crop production is concerned. It is sound policy however to add a small quantity about every fifth year. In this manner the soil is made more permeable and takes on a better tilth, better green crops are obtained and the tea bush appears to be less affected by certain diseases. For example, the root disease *Ustulina zonata* is apparently less liable to attack the bush if liming has been carried out.

With regard to light soils, many of these, especially the newer ones, are deficient in organic matter. At Borbhetta, excellent results have been obtained from the addition of cut jungle which increases the organic content of the soil.

On the newer soils, especially the less acid ones, manures of an acid nature should be added, *e.g.*, sulphate of ammonia, superphosphate, muriate of potash, whilst liming or the addition of alkaline manures, *e.g.*, nitrolim, basic slag, should be carefully avoided.

The table below may be taken as a rough guide for a five year rotation on older and newer soils of the Dhunsiri district.

Newer Sandy Soils.	Older Red Soils.
1. 7½ mds. crushed limestone per acre, broadcasted with first light hoe.	10 mds. slaked lime per acre broadcasted with first light hoe.
5 tons cattle manure per acre.	5 tons cattle manure per acre.
2. Green crop, *e.g.* cowpeas. 1 cwt. ground rock phosphate, broadcasted up seed beds.	Green crops, *e.g.* cowpeas. 2 cwt. ground rock phosphate broadcasted up seed beds.
3. Muriate of postash ... 40 lbs. Fish manure ... 300 „ or Muriate of potash ... 40 „ Oilcake ... ... 7½ mds. per acre, forked round bushes in April.	Sulphate of ammonia 150 lbs. per acre, forked round bushes in April.
4. Boga medeloa ; also fork mixture round the bushes as in 3.	Boga medeloa ; also fork mixture round the bushed as in 3.
5. Trench in Boga medeloa ; also fork mixture round bushes as in 3.	Trench in Boga medeloa ; also fork mixture round bushes as in 3.

The mixture may be omitted from Nos. 4 and 5 in case expenditure will not allow of the full rotation, but the inclusion of this mixture is economically sound.

TEA NURSERIES.

H. R. Cooper, B.Sc., F.C.S.

In planting out a garden the most important consideration is the production of good young plants. A poor plant, no matter how well treated afterwards, will never be equal to a good plant untreated. Poor plants put out in good soil will develop into useful bushes but will never be equal, as leaf producers, to a good plant in the same soil. When plants are required for infillings, it is even more important that only really good plants should be used. One sometimes sees only a miserable hide-bound stem carrying a few diseased leaves after the plant has been in the ground several years, and this is nearly always due to the use of poor plants.

In some districts favourably situated with regard to soil and climate, there is no difficulty in producing a fine nursery without special precautions unless in exceptional seasons. These districts are those where the best average tea is found although there are other districts of better average soil. The factor which is so favourable in these districts is a relatively cool and wet period following the planting of nurseries.

In this respect the best district is undoubtedly Upper Assam, particularly the Doom Dooma district, while the worst are the South-Western end of the Dooars, the Terai, and the lower end of South Sylhet, where a relatively hot and dry " cold " weather, followed by a near approach to the real " hot weather " of the plains of India preceding the monsoon, is experienced.

The districts of Lower Assam—Nowgong to Jorhat—are intermediate. In Jorhat, for example, good nurseries are easily produced in good seasons, particularly when the nursery site is on cleared jungle land of good soil, where the trees surrounding the site serve an important purpose by acting as a break to dry

Fig 3.

Shaded nursery on manured soil
which had carried nurseries
in 1917-18 and 1920-21.

Fig 4.

Distant view of shaded nursery
showing construction of
framework for shade.

Fig 1.
Shaded nursery on jungle soil.
Plants are approximately
9" high.

Fig 2.
Unshaded nursery on good soil.
Close examination shows blackened,
bare sticks which are all that
Brown Blight has left.

winds and a shield from the western sun. In bad seasons and in exposed positions however, failure is often experienced. This is a matter of painful personal experience on this station, which has led to careful observation of the factors making for success and failure respectively.

These notes do not represent the opinion of the writer only, but also embody the results of observation and experiment by other officers of the department, particul. rly Hope, Carpenter and Wiles.

Probably a few only of the observations will be new to any one planter of experience. In fact it is claimed that most of the recommendations have stood the test of practice on more than one garden; and many of the experiments mentioned were made to measure the effect of an operation, the efficiency of which had previously satisfied more than one successful nursery maker in practice.

An attempt has been made to indicate the nature of the differences caused by variation in soil and climate, but in nursery making, as in other planting operations, a lot must be left to local experience.

Moisture.—This is undoubtedly the most important factor. With favourable rain a good nursery is assured, particularly as the prevalence of showers means cloudy skies and absence of scorching sun.

Watering by hand removes most of the troubles, but will not, of course, reduce the scorching effect of the sun on delicate young leaf and stem, and does little to produce the moist atmosphere which is so favourable to the young tea plant. Watering also involves much labour, and is often impossible owing to the absence of water.

Shade.—A moist soil and a moist atmosphere are both maintained by shade, and in droughty districts shade is found to be essential. In Upper Assam it is usually found sufficient to conserve soil moisture by a few inches of thatch laid on the soil, and this thatch is removed when the plants are a few inches

high. In exposed situations, however, the young plants are very commonly seriously attacked by diseases following the removal of the thatch, which diseases may produce effects so serious as to leave no plants really worth putting out. These diseases are undoubtedly brought on by undue dryness of the soil and by sun-scorch.* They can be ameliorated by watering and by manuring, for which latter purpose a mixture of equal parts nitrate of soda and nitrate of potash at 2 cwt. mixture per acre has been found very useful. "Liquid manure" made by fermenting cattle manure in a barrel with water is also good. Spraying, if done in time, will also be useful. The diseases however can be altogether avoided if light shade is provided, and kept up.

In districts where shade is always provided it is generally made about 1 foot from the ground on the south side sloping up to about three feet on the north. It is very commonly observed that under such shade the young plants are unduly drawn up, they become weak, and it has been noticed on occasions that the plants under the shade which is nearest to the ground are so poor as to be valueless. Such shade also has to be removed too early in a droughty season.

Several experiments have been made at Borbhetta on various methods, and undoubtedly that which produces best results is flat shading 5 feet or more from the ground, covering the entire nursery. It resembles the shade under which *pan* is grown.

This shade must be made to stand up to high winds. The uprights must therefore be well driven into the ground fairly close together. The shade is of very thin thatch between split bamboos to make panels which are firmly tied to bamboo cross-pieces.

We usually place thatch on the beds, after sowing and watering, and then proceed to erect the framework for the shade,

* See Tunstall, Quarterly Journal, 1916, Part III, p. 103.

and after that use the thatch from the ground to make panels to tie on to the cross-pieces.

Fig. 1 shows a nursery so shaded. This nursery was never watered, except just after planting, for during the dry weather even drinking water had to be carted from three miles away. Fig. 2 shows a nursery made at the same time, the only shade being thatch laid on the ground.

The photos were taken on July 4th, 1924.

At Borbhetta the cost of high shading is estimated at Rs. 200 per acre of nursery. Costs on a garden where bamboo and labour are more cheaply obtainable would be less.

At 8 inches by 8 inches triangular planting, allowing for drains, we get the good germinated seed from nearly 5 maunds of seed into an acre of nursery. The cost of the seed is therefore already about Rs. 500 per acre, to which must be added cost of preparation of nursery, planting, watering and weeding; so that the cost of the shade is not a large percentage increase on the cost of the nursery, while it will sometimes make the difference between complete failure and complete success, and nearly always produce considerable improvement.

The shade is best kept up for the whole of the first year, the thatch being gradually thinned out.

Shade when provided is often removed too early. One of the disadvantages of low shade is that it has to be removed too early. Letters forwarding specimens of dead seedlings, and stating that the nursery was excellent till soon after shading was removed, have been received as late as July.

Shade is sometimes provided by sowing boga medeloa either among the tea seed or in lines between the beds. As the boga medeloa grows much quicker than the tea its shade is of some value, but is not sufficient early in the year when the tea most greatly requires it. The boga medeloa also takes water at a time when it may be badly needed by the tea plants. If used, it is best sown in hedges at least a foot from the nearest tea plant, and kept lopped up the sides to avoid smothering the nearer tea

plants. It is of course more efficient if planted well before the tea seed is sown so that it may be high enough to be useful from the time when the thatch is lifted. It should be planted in lines running north to south and never allowed to be too thick.

Soil Factors.

In selecting a site for a nursery a good sandy loam should if possible be chosen as likley to give the best nursery; but a nursery for planting out a clay should not be made on a sand, because the tap-root on emerging from the sandy clod may be turned horizontally on meeting the clay. Plants will grow on a clay, if the surface soil is sufficiently good either naturally or artificially.

Manuring.—Since a large quantity of food is stored in the seed for the use of the young seedling, the food provided by the soil is not, at first, of importance. Very good seedlings can be grown in silver sand which provides no food. As a general rule however an additional supply of potash is of value to a seedling, and tea is no exception. On soils deficient in potash (as many sandy soils are) potash manuring is of value even within the first few months of growth.

Of more importance is the physical condition of the soil, largely because this is so intimately connected with the all-important water supply to the plant.

Nurseries present the greatest difficulty on excessively sandy soils in a droughty district, merely because the sand so readily dries out. In that case much can be done by increasing the water-holding capacity of the soil by addition of organic matter. On heavy soils improvement of the texture is equally important, since these also suffer from drought, and, in addition, from restricted root range. For this improvement well-rotted cattle manure mixed to a good depth is ideal.

Cattle manure however carries so many jungle seeds that such an application may produce a choking growth of jungle

before the young plants have reached a size when they may be weeded with safety. To avoid this the cattle manure should be applied early (August) and the weeds destroyed, after germination, by hoeing. Three applications of the hoe will leave a bed practically free from weeds, if time is allowed for germination, but not for seeding, between each round. Such hoeing should be shallow only, or seed deep enough not to germinate may be brought to the surface to grow. This cultivation will also expose to attack by birds the root-eating grubs introduced by the manure. The lighter cultivation is conveniently and cheaply performed by a bullock-drawn cultivator which is always followed by crows, who do not leave many grubs.

A good growth of a green crop may serve the same purpose as the cattle manure. In this case also the green manure should be hoed in early. We do not want organic matter decomposing in the soil when the seed is planted, because the soil is then charged with carbonic acid, to the great detriment of the germinating seed. At least two months should be allowed between application of any form or organic matter and sowing of seed, and rotting should be assisted by one or two applications of the hoe.

Where nitrogen is not provided before planting, as cattle manure or green stuff, it is best to withhold it till the plants are about 4 inches high, and then provide it in available form. For this purpose liquid manure is excellent, but is troublesome in preparation and application. Two cwts. nitrate of soda per acre gives very good results. It should be broadcasted and lightly forked in.

Burning.—The soil is also very greatly improved (temporarily, but long enough to affect a nursery greatly) by heat. It is quite common to find a stand-out bit of nursery on the spot where the rubbish was burnt before the nursery was made. Burning the soil is practised with good results by the cultivators of Western India before making nurseries for rice, and the effects of this burning were investigated by Mann, Joshi and

Kaniktor.* This is not the place to give long extracts from their interesting paper, but the following points are of practical importance :—

1 Normally the weight of seedlings obtained is from one and a half times to twice as great as without the treatment.

2 Of this increase 60 per cent. is due to the effect of the heating, and 40 per cent. to the ash and other materials added.

3 The greatest effect is produced when the heating is conducted immediately before sowing the crop. Heating three months before sowing produces little effect.

The effect is considered to be greatest on clay soils.

Experiments conducted at Tocklai on a tea-nursery showed the following similar results :—

Heating the soil by means of boiling water alone gave excellent results. Ashes burnt elsewhere and carried on to the beds also produced great improvement; but in experiments using each of the constituents of the ash separately only potash proved useful, phosphoric acid and lime each gave somewhat poorer nurseries than untreated soil. This of course is probably not true of all soils, but will hold for very large areas in the tea districts.

None of the beds were equal to that on which rubbish was spread over the surface and burnt there, so that the soil had the benefit both of the heat and of the ash.

In addition to producing better plants, both this treatment and the boiling water also produced almost complete absence of vacancies, no doubt by killing out organisms, large and small, which attack seedlings.

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* Memoirs Dept. Agric. India, Chem. Series.

" The Rab System of Rice Cultivation in Western India."

Fires made to burn slowly in covered trenches were not so effective.

In places where nurseries have to be made on poor land, as when tea is uprooted for replanting, this method should be found useful. The uprooted tea bushes will provide the fuel. In the Tocklai experiment plants from an abandoned nursery were used. These were spread loosely about 6 inches thick over a few inches of old thatch and left to dry, when they were easily burnt.

Example of Good Nursery on Poor Soil.—Fig. 3 shows a nursery planted in December 1923, on a site where nurseries had previously been made in the cold weathers 1917-18, and 1920-21. In both cases good nurseries were produced, which means that the greater part of the top-soil was carried away on each occasion when the plants were lifted with clods of earth.

On each occasion during the season following the lifting of the plants the old nursery was generously treated with cattle manure, and cowpeas were sown in spring and hoed in near the end of the rains. In each case old, woody boga medeloa stumps were burnt on the surface before planting.

It is a good plan to plant boga medeloa in the spring following the hoeing in of the first season's green crop, and leave it growing till the land is required. Leaf fall and root-action will add to the fertility of the soil, and the land occupied by boga medeloa will not grow much thatch or other objectionable jungle. When the land is wanted for a nursery, the woody boga medeloa can be pulled up, left to dry, and burnt.

About two months before the photo (Fig. 3) was taken this nursery was dressed with nitrate of soda and is showing good effects. The nursery is a good one,—very satisfactory indeed in view of the previous history of the soil and the very unfavourable season—but is not quite so good as the nursery shown in Fig. 1, planted with no special treatment on a strip of land cleared on the edge of tree jungle on the boundary of the estate. Only the want of enough land of this kind enforced the use of

the old nursery site, on which trouble and money had to be lavished.

Jungle land is always well supplied with organic matter and all necessary foods, and it is always in perfect physical condition. Such land however is not always available, and in that case the above notes may prove useful.

In the photos, Fig. 3 shows better beds of plants than Fig. 1. Fig. 3 shows the beds where the seeds which germinated first were planted. Fig. 1 shows the beds where the last germinated seeds for this nursery were planted. The seeds which germinate quickly always give bigger and stronger plants than seeds which are slower to germinate.

The beds of first-germinated seed of the nursery on jungle soil could not be photographed, because the light at that end was insufficient. On the whole they are a little better than those on the old nursery site.

Preparation of Land.

Depth of first hoe.—The better the soil is broken up the more easily will a straight deep tap-root be obtained. Within reason therefore the deeper the hoe the better from this point of view. We have however to remember that we want to lift each plant, when grown, with an unbroken clod of earth about its roots. By "clod" is meant what is called in Assam *bheti,* in the Dooars *dela,* and sometimes *bhindi* in Sylhet.

On a heavy soil there is seldom any difficulty in taking an unbroken clod, and in any case a soil containing much clay only too soon regains its compactness, because it expands so much on wetting. On sandy soil, however, not only do roots naturally find less difficulty in penetration, but it is essential to regulate the depth of hoeing so that some portion at least of the root is in unbroken naturally compacted earth, in order to keep the number of broken clods as low as possible. On sandy soils, therefore, there are good reasons for not hoeing too deeply.

Soils mainly composed of fine sand (as they are generally at Borbhetta) set very hard when undisturbed; yet disturbed soil remains very loose even after a year, although the surface cakes readily on drying after rain.

Hoeing to 8 inches only does not give us plants as good as when we hoe to 15 inches, but in the latter case with all possible care a very large number of the clods are broken in lifting or carrying. In practice we get about the best results by hoeing to 9 or 10 inches. At the end of a year we then take a clod 14 inches to 15 inches deep, the delicate young root tip being then protected in compact soil which does not easily break, and with 5 or 6 inches of hard soil at the bottom the plant in its clod can be handled without much fear of undue breakage.

The depth to which it is advisable to hoe thus varies with the soil, and the best depth is usually pretty well known to practical planters in each district. It varies between 12 inches or more on clay to about 6 inches on coarse sands, though it may be necessary to go deeper to get out roots of bad jungle.

Removal of jungle.—The most important point in preparing the soil is to see that it is made free of all kinds of jungle which cannot afterwards be dealt with by surface weeding.

Soil from cleared tree jungle usually remains free of anything but surface-rooting grass and weeds. The only mistake possible there, is to leave a tree, which means a ring of vacancies around it, the size of the ring depending mainly on the size of the tree. Such a mistake of course is very seldom made.

Nurseries however very often have to be made on old thatch reserves, grazing ground, waste land, or grass jungle. On all these the main object of the preparation of the land is to get rid of grasses like *ulu* or *kasi* which grow from deep underground stems. It is no good simply to cut these stems—a new plant grows from every knot—they must be dug out, as completely as possible.

One or two more cultivations are generally necessary to get the surface free of weeds and well pulverised for the seed

bed. After beds are made up the Planet Junior wheel-hoe is useful in preparing the surface soil.

It is well to get all this done early. The soil pulverises better when just moist enough (especially clay) and it is better to plant in moist soil than in dry dust which has to be soaked by carried water, often not too good for seedlings.

Drainage.—It is the usual practice to make up the nursery into beds about 6 feet wide, with 1 foot drains between them. Such close drainage is not necessary, but it makes certain that no part of the nursery is spoilt by lying under surface water. The space is not wasted since the drains serve as paths from which the beds may be watered, weeded and manured when necessary.

If deeper drains are necessary they will of course be outside the nursery.

Planting of Seed.

Distance apart.—It is most common to plant seed 6 inches or even 4 inches apart, for the sake of keeping down cost per maund of seed sown. It would be sounder to consider the cost per first class plant produced and if that were done 6 inches would generally prove dearer than wider planting, except when it is intended to plant out 6 months old plants.

Actual experiment at Tocklai* gave the following average results with two-year old plants.

Distance apart of seedlings, inches.	Average weight per 100 plants, ounces.	Average height, inches.	Average circumference at collar, inches.
4	43	56	1·14
6	56	50	1·48
9	82	47	1·80
12	98	43	2·03
18	128	40	2·20

* Quarterly Journal, 1915, Part III, p. 36.

With increasing distances apart, weight and thickness increase very considerably, but height decreases. To look at, the closer planted nurseries were very much the higher, but average heights are reduced by the very large number of plants which are crowded out and reach a very small height. Close-planted nurseries grow high plants, vacancies are not noticed, and they look better than they are. Observation usually shows a much higher percentage of good plants near the outside than in the crowded middle, where a lot of expensive seed has been wasted altogether, and few plants are really good.

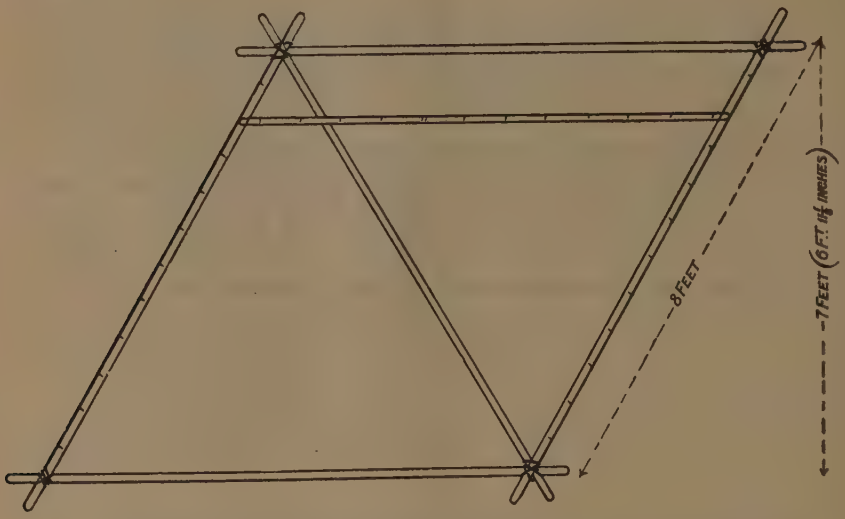
Our own experience would lead us to advise :—

for 6 months plants, plant 5 ins. apart.
,, 12 ,, ,, ,, 8 ,, ,,
,, 24 ,, ,, ,, 10 ,, ,,

We plant triangular, not square. We get about 14 per cent. more plants to the same area, each plant is no nearer to its neighbour, and planting is just as easy or easier.

In our own case we usually make beds 7 feet broad. We then take 3 straight pieces of split bamboo about 9 feet long. On each piece two notches are made exactly eight feet apart. The three bamboos are tied together to form an equilateral triangle with sides 8 feet long. Two similar bamboos are then tied on to complete a diamond shaped figure of which each side and the diagonal are 8 feet long (outside measurement). Two opposite sides are then marked by notches 8 inches apart. This figure is laid on the seven-foot bed which it covers leaving a fraction of an inch over. Another loose 8 foot bamboo with notches 8 inches apart, the first and last notches being 4 inches from each end, is then laid over the figure so as to join the first pair of opposite notches on the sides of the diamond. The notches on the loose bamboo indicate the places for the first 12 seeds, and so on. The sketch will make this clear.

If a bed of different breadth is preferred, the diamond shaped figure should have sides equal to 1.155 times the breadth of the bed.



Germination.—The tea seed contains, inside a hard shell, a white kernel. The kernel consists of two halves (called cotyledons) naturally divided as if by a clean cut. Lying between the two cotyledons, and joined to each of them, lies the young plant (called the embryo) in which the embryo root and embryo stem can easily be distinguished. The two cotyledons carry food stored for the use of the immature plant until it is able to find its own food in the soil.

On the outside of the hard shell is a scar, marking the place where the shell was joined to the green seed-coat. This scar is commonly called the "eye." The embryo root, as it lies in the seed, is always directed towards this eye, and the embryo stem directly away from it.

If we want a straight plant it is only natural that we should place the seed so that the young plant is upright to start with, and neither standing on its head, nor lying on its side. Seed therefore should be planted with the eye down.*

* See Quarterly Journal, 1916, Part III, p. 105.

With ungerminated seed the necessity of looking for the eye makes the operation of planting a little more lengthy and expensive, and is therefore not in perfectly general favour. It is objected that in nature the tea seed falls anyhow. That is true, but under natural conditions the seed is not buried but lies free to move. The young root first emerges and turns towards the ground which it enters, and in so doing, turns the seed upright. This turning does occur even with buried seed, but not in every case. Experiments have shown that in beds planted with the eye down the percentage of bent plants is negligible, while there are many bent plants if the seed is placed in any other way.

Stones in the soil will of course cause roots to bend to pass the obstruction. The soils at Tocklai and Borbhetta (where experiments were conducted) contain not a single stone, (not even a little one) so that any bending must clearly be ascribed to some other cause.

If a seed is planted with the eye at the side it usually turns out very well so long as the cotyledons happen to be lying vertically. If however the cotyledons are lying horizontally, one on top of the other, then the young root grows towards the eye and on getting out of the seed, turns through a right angle and grows vertically downwards as roots will if nothing stops them. The young stem being held between the cotyledons, is forced to travel horizontally till it gets out of the seed, when it turns at right angles and grows vertically upwards as stems will if they can. Thus we get a plant with two right angled bends in it, which persist as a kink near the collar for many years, and these kinked plants are very seldom good.

If the seed is planted with the eye at the top, the bending is not usually so pronounced, because the young plant breaks clear of the seed. The root however then has to bend round the seed. With the eye at the top therefore we get more slightly bent plants than with the eye at the side, but not so many badly bent.

With the eye at the bottom the hard shell nearly always splits normally so that the two cotyledons spring apart leaving a clear passage upwards for the young stem. With the eye at the side abnormal splitting more often occurs, so that the stem or the root does not find its way out of the seed at once, but completes a circle, and sometimes several eucles, before emerging from the seed.

It is recommended therefore that seed should always be planted with the eye down, whether germinated or ungerminated.

In deciding whether to plant seed ungerminated, or after germination, the chief consideration is the quality of the seed. If, on opening, a very large percentage show sound white kernels without a spot of fungus, it is not only less trouble, but much better to avoid the extra risk of handling germinating seed. Seed however has not been uniformly good, and the use of germinated seed has saved a large percentage of vacancies and poor plants, in many cases.

The rate of germination also is a very good test of the goodness of a seed. Those which germinate quickly always make the best plants. With good fresh seed about 80 per cent. germinate within a month, and those which take much longer do not give good plants. The seed that has not germinated in about 2 months we usually plant about 4 inches apart, and afterwards weed out the poor plants to leave a few that will be useful. If seed is first germinated it must be examined frequently, and all those seeds which have cracked planted out at once, before the young root has time to get bent. The best seeds germinate in about three weeks.

When the wet germinated seed is carried to the beds for planting, it must be carefully preserved from drying. The basket carrying the seed should be covered, and only so much seed taken at a time that can be planted in about an hour.

Germination is best in clean sand, which can be kept wet, but drains freely enough to prevent water-logging. The pres-

ence of organic matter (even so much as occurs in a good soil) is objectionable, since it decomposes to give carbonic acid, which hinders, and in excess can prevent, germination.

The young root always comes out of the seed first, we have therefore no need to look for the eye on germinated seed, but simply place the root downwards. If however the seed has been too long in the germinating bed, so that a long root has formed, the plant is already bent unless the eye happened to be downwards in the germinating bed. Therefore the germinating seed must be examined frequently.

If a few seeds have long roots not growing straight away from the seed, the best thing to do is to pinch off the rootlet and plant the seed with the root-stump down. Experiment has shown that a good plant will still develop, but it will have two or three main roots instead of a single tap-root. The single tap-root going straight down is very much to be preferred for soils through which penetration is difficult, and particularly for clay soils which get heavier with increasing depth. On such soils any root not absolutely perpendicular, turns off more and more as it meets increasing resistance till it finally becomes horizontal. On the sandy soil at Tocklai the seeds whose rootlets had been pinched off gave plants just as good up to three years (when the experiment ceased) as the normally planted seeds.

Depth of Planting.—In the jungle the seed falls on the ground, and grows perfectly well without being covered except by leaves, but in that case it is well shaded and protected from drying. The greatest mistake that can be made in planting is to put the seed in too deeply. In a shaded nursery plants grow perfectly well when the soil has washed away to expose the upper half of the seed (so long as the eye is covered), but a plant with its seed so exposed will not do well in the sun. Even in an unshaded nursery half an inch of soil over the seed is ample while if the nursery is to be shaded it is enough if the seed is just covered. Seeds one inch deep only come away a little more

slowly; but of seeds much deeper than that some fail to come through.

Method of Planting.—The pointed stick to make a round hole is objectionable. It is very difficult to regulate the depth and one cannot tell whether or not the seed will turn over when dropped into the hole. The stick also polishes and makes less permeable the sides of the hole.

A well-prepared nursery should have a surface of loose fine soil. A little of this should be scraped to one side with the hand to about 1 inch deep, and the seed placed, eye down, on the scraped surface. The soil is then replaced over the seed. One of the most successful nursery makers has used this method in the Jorhat district for many years before Tocklai experiments started. He however covers the seed, placed in the scraping, with soil carried from the jungle. The jungle soil is not so likely to form that hard surface crust, through which the young stems force their way only with difficulty so that some become bent and spoilt in the process. This surface crust however never gives serious trouble under shade, nor on normal good soils, and there is seldom any need to carry jungle soil for covering seeds except on soils largely consisting of fine sand without much organic matter.

Watering.—The beds planted as described should be well soaked at once, particularly if ungerminated seed has been used. A shaded nursery will want very little more water. Whenever water is applied the beds should be pretty well soaked. A sprinkling to wet the surface does not penetrate far, and only serves to cause the formation of the objectionable hard surface crust, when it dries.

Cultivation after Planting.—It will be necessary to remove weeds whenever they become too thick. The first weeding should be postponed till the plants are strong enough not to be damaged while the weeding is in progress. This first weeding among small plants is safest by hand, afterwards we have found that a Planet Junior Two-wheel Hand-cultivator does excellent

work at a very cheap rate. On this hoe the two wheels are connected by a hoop which goes over the line of young plants.

Jungle growth is reduced under shade.

Seed.—Selection and testing of seed do not come within the scope of this article. On testing, notes are given in Quarterly Journal 1914, Part I, page 1.

However good the *jat* of seed and however well packed it may be, it must be sown while fresh if first class results are to be expected. The sooner the seed is in the nursery after it has left its parent tree, the better.

On two occasions, owing to breakdown of transport, seed has been received at Borbhetta in February. Only apparently good germinated seed was planted in March. Both nurseries were hoed in as useless. The same seed received in November of two other years gave excellent nurseries, one of them the best we have ever had.

THE CONTROL OF SOIL MOISTURE.

P. H. Carpenter, F.I.C., F.C.S.

After having experienced monsoon conditions in North-east India one may be tempted to consider the climatic conditions of this part of India to be entirely of a humid, semi-tropical character, but this is by no means the case. True it is that during the rainy season many of the problems of tea are concerned with the removal of excess water from the soil but these conditions do not prevail after the recession of the monsoon, and throughout the tea districts of North-east India conditions tend to approximate toward the arid. At this time of the year it is not excessive moisture but lack of moisture that becomes the problem and great care and attention need to be given to this question if the tea is not to suffer from drought. The soil moisture conditions throughout the year at Tocklai illustrate this and are shown on the accompanying curves (*vide* Fig. I).

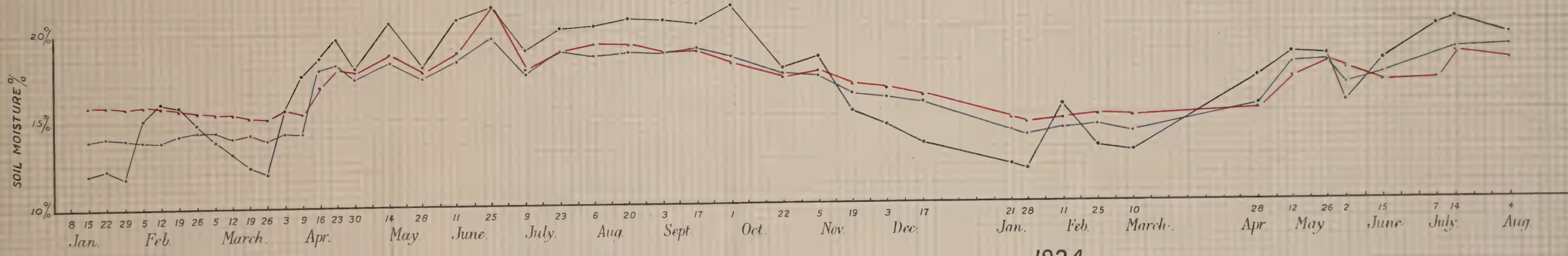
These arid conditions are more marked in some parts of the tea districts than others. The further south and west the district is, the more do these conditions pertain, South Sylhet and the Western Dooars representing the most arid districts and the eastern end of Assam the least arid. The more severe drought conditions in the Surma Valley and the Dooars are perhaps not so much due to any difference in rainfall but to the higher temperature and hence a lower relative humidity of the atmosphere and a greater rate of evaporation from a water surface.

The severity of the drought, however, does not compare in intensity with that experienced in other countries. For instance, the annual rainfall in North Dakota is only 13 inches and during the six dry summer months the evaporation from a free water surface amounts to 31 inches, yet it is possible successfully to grow crops if careful precautions are taken to conserve

SOIL MOISTURE % 1923 TO 1924.
KHARIKOTIA PLOT, BORBHETTA.

= 6"-12"
24-30"
36-42

FIGURE I.



the soil water. A very important difference however exists between these conditions and those in the tea gardens, for in North Dakota the land only bears crop for a short period of the year whereas here the land carries the tea bush throughout the entire year which calls for a constant and continual supply of water.

Soil type.

It is the purpose of this article to discuss some of the means whereby drought effects may be minimised on tea gardens. Perhaps the first factor that needs consideration is the soil, for the type and character of the soil greatly affects the problem.

A small grained heavy soil not only impedes the downward growth of the tea roots but also hinders the downward percolation of water during the rains. Such soils readily become water-logged with the result that the bush develops a surface root system. This may be quite satisfactory in the rains but when rain no longer falls the top soil is likely to become very dry and the bush consequently suffers owing to the absence of any deeply penetrating roots that could obtain water from the lower soil levels.

One of the first considerations for such a soil is a system of drainage that will remove soil water from near the surface as quickly as possible so as to prevent water-logging and, since percolation of water is very slow, the drains will need to be close together (20 feet apart). However it is not necessary that they be very deep as it is required to remove the water before it has penetrated far into the soil. A maximum of three feet depth should be ample for such soils.

In the case of sandy soils the water can percolate quickly and the surface soil is unlikely to become water-logged unless the permanent water during the rains rises very near to the surface, *i.e.*, three feet. If the rains water table is at any considerable depth below the surface such soils are probably not in need of artificial drainage. When the water table rises in the rains to near the surface, then the bush develops a shallow root system which, owing to the inability of sandy soils to raise water to any

extent, leaves the roots high and dry when the water table recedes to a lower depth in the cold weather. In this case it is necessary to lower the rains water table as far as possible and large deep drains are necessary, but owing to the ease with which water can percolate, such drains need not be close, *i. e.*, 80 feet apart. Both with heavy and light soils it is required that a deep rooting system for the bush be established.

Plant roots.

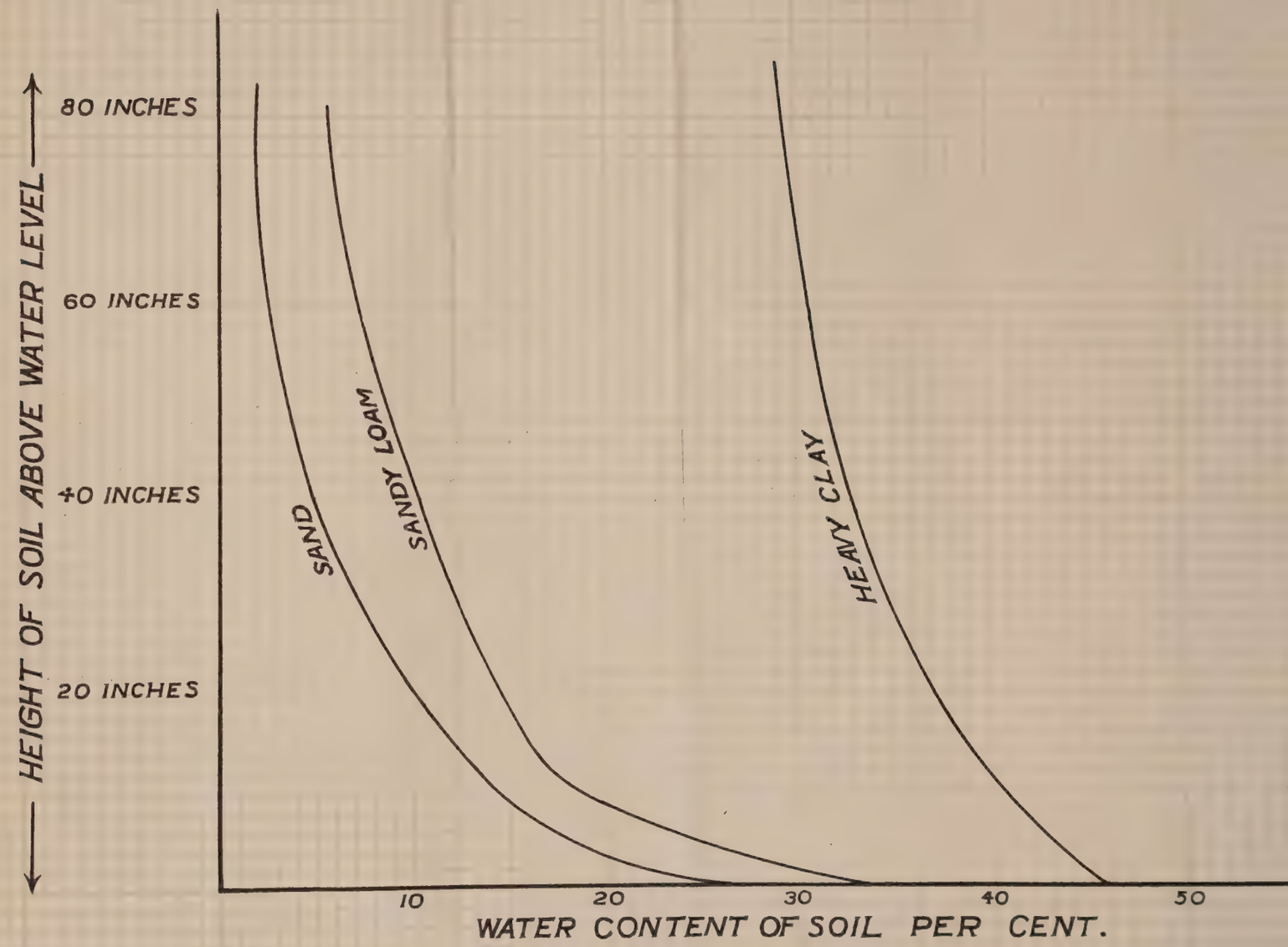
It is necessary in all soils that the plant roots in the dry weather shall approach the cold weather water table to the depth at which water is available for the full needs of the bush. In a heavy soil which can lift water to a much greater height than a sandy soil it is not necessary for the roots to reach so near the water table. Although a heavy soil c n lift water yet it can lift it but slowly and bushes in a heavy soil need to have a well spread root system otherwise the soil water will be removed from the soil in the neighbourhood of the roots more quickly than it rises through the soil. Consequently the soil will become dry and drought conditions may obtain. Sandy soils cannot lift water to any great height. It is therefore essential that the tea roots shall penetrate downwards in the soil until they reach a depth at which water can be obtained in sufficient quantity during the period when the water table is at its lowest.

It must be borne in mind that the roots will not develop downwards below the depth to which the water table rises in the rains. It is necessary therefore to ensure by drainage that no very great difference exists between the wet weather water table and the depth at which water is available for the full needs of the plant during the dry weather.

Bheel soil.

In the case of bheel soils where the root system is a very shallow one, every precaution must be taken to maintain the water as near the surface as possible during the cold weather and on no account should a real peat bheel be drained with any other form of drains than shallow ones 2-2½ feet deep. In order to remove the water during the rains these shallow drains will have to be wide or close together.

FIGURE II



CURVE SHOWING WATER CONTENTS OF DIFFERENT SOILS, AT VARYING HEIGHTS ABOVE WATER LEVEL, AFTER EQUILIBRIUM HAS BEEN ATTAINED.

Bheel soil is incapable of lifting water more than about 2 feet, and it is consequently very desirable that such areas should be irrigated in the cold weather. Any streams running through the bheel should be utilised for this purpose. It is of interest to note that if a bheel soil can be kept moist up to the surface in the cold weather very little sinking will be noticed.

The actual depth to which it is necessary for the tea roots to penetrate in any soil varies according to the depth of the cold weather water table and the type of the soil. This depth can only be satisfactorily determined by moisture determinations on the soil at various depths during the time when the water table is at the greatest distance from the surface. The roots should go down to a depth where the soil moisture is never much less than the optimum water content* for that soil, and the problem of drainage in the wet weather is to see that at such a depth the soil never becomes water-logged. It will be noted from the above remarks that the question of soil drainage does not require only the study of water conditions in the rains but also of equal importance the soil moisture conditions in the cold weather.

Reference has already been made to the upward lift of water in the dry weather. The water is lifted in the form of a thin film spread over the surface of the soil particles. The thickness of the film depends on the shape and size of the particles, also on the distance from the permanent water table. That is to say, the greater the distance from the water table the thinner does the film become. Consequently the less water will the soil contain the further away from the water table it may be.

The attached curves (Figure II) illustrate the water lifting capacity of different soils after they have attained equilibrium which occurred only after a long period of time.

In the case of the sand it will be noticed that at 20 inches above the water level the soil contained only 10 per cent. of water which in this case is approximately the optimum water content. At 40 inches above the water level the soil contained only 5 per

* *Vide* Quarterly Journal 1921, Part III, p. 145.

cent. water which would be insufficient to supply the needs of a growing crop and drought effects would be evident.

The curves clearly illustrate the incapacity of a sand to lift water to any height. In order to prevent plants on such a soil suffering from drought every precaution must be taken to prevent evaporation from the soil surface, or unnecessary loss from transpiration of the growing plants, so as to husband the water left in the top layers of soil at the end of the rains.

In the case of a heavy clay soil the water lifting capacity is so great that the soil is too wet even at the surface of the soil when the water table is 80 inches away. Such soils can only be kept in a suitable condition for plant growth by evaporation of the water from the soil surface, and such evaporation must be encouraged in the wet weather. Atlhough the water lifting capacity is so great it is very slow and in the dry weather the rate of evaporation from the surface will far exceed the rate of lift, which indeed is almost negligible. Care must therefore be taken in the dry weather to prevent evaporation from the surface or the soil will be gradually dried out. This is of particular importance in the case of such soil where the roots penetrate to only a very slight depth into the soil.

A study of this Experimental Station soil moisture records shows that on a sandy soil of the type found at Tocklai the soil moisture varies but little at a depth of 3 feet and if the roots of bushes can be made to penetrate into the soil to this depth they will feel but slightly the effect of drought. Both with a clay soil and also a sandy soil that is removed from the dry weather water table more than 4 or 5 feet, precautions must be taken to prevent evaporation of soil water from the surface as the water lifting power of the soil is insufficient to provide the requisite quantity of water required in the necesary time and to protect the growing bushes from drought effect.

Mulches.

The thickness of the water film at the soil surface may be very thin indeed but that will not prevent the film in contact with the atmosphere evaporating. More water will

then rise to produce an equilibrium and this in turn will be evaporated with the result that a continual evaporation of water takes place on the surface, and there is a continual loss of water from the soil. It is this continual drain on the soil water, during the cold weather, which it is necessary to prevent or at least to minimise during the dry weather.

It is obvious that if the water film could be prevented from reaching the surface, and consequent exposure to the atmosphere, much of the loss of water by evaporation could be prevented. This can be done. Leaves falling from a tree cover the soil and prevent evaporation. Such a mulch need not be made of leaves, but anything spread over the surface can be employed, and in some cases of intensive cultivation paper sheets have been employed. Jungle of all descriptions pulled up and allowed to lie on the soil surface without being hoed in provides an excellent covering, and on some tea gardens this form of treatment has been carried out successfully.

Another covering that has been found efficient is a layer of dust on the soil surface. This is perhaps the most practical manner of obtaining a soil covering as this can be obtained on any soil by light hoeing. As soon as may be possible after the end of the plucking season such a mulch should be made on the soil surface and a light hoe done to break up all lumps and to powder the soils necessary. The depth of the hoe is of comparatively little importance, for a depth of three inches of loose dry soil is sufficient to prevent most of the evaporation from the soil. Such a dry layer cuts off the film of water of the consolidated part of the soil below the mulch, from evaporation by the atmosphere.

Here arises one of the troubles. Small showers of rain of perhaps half an inch or less fall and are just sufficient to thoroughly wet the 3 inches of loose mulch and cause its consolidation to such an extent that the soil water films can be formed and it then forms again part of the soil mass and lifts the water in a film to the surface where evaporation occurs. Its value then, as a protection against loss of water, is completely lost and will

remain so until it is again light hoed and broken up into a loose dusty like layer.

Small showers of rain in the dry weather by thus destroying the protective covering cause a greater loss of moisture from the soil than would have occurred if no rain had fallen. After a fall of rain the mulch must be remade. This must be borne in mind in those districts that experience rain showers at about the end of the year, and on gardens that are short of labour it is better to postpone the preparation of the mulch until the commencement of the year. Here it should be noted that it is far better at such a time of year to light hoe so as to make a three-inch dusty mulch rather than do a deep hoe which will be hard and slow work and probably result in turning up clods which provide practically no protection from loss of water from the soil.

The following figures show clearly the protecting effect of a surface mulch of loose soil. They were obtained by King in Canada :

	Mulch depth			
	1″	2″	3″	4″
Light sandy soil, % of water saved ...	34%	54%	61%	57%
Clay loam, % of water saved	48%	59%	63%	63%

The following figures obtained by Buckingham in America also show the protective value of a soil mulch :

1 inch mulch 2.7 inches of water lost per annum by evaporation.
2 ,, 1.60 ,, ,, ,, ,,
4 ,, 0.95 ,, ,, ,, ,,
6 ,, 0.69 ,, ,, ,, ,,

The effect of a soil mulch produced by light hoeing is shown by the following figures obtained at Tocklai. In February 1.92 inches rain fell and the soil moisture rose to 18 per cent. but then began to fall quickly. Part of an area was then hoed and part of

the area was left unhoed. The moisture content of the two areas during the ensuing days was as follows :

No. of days after hoeing.	Hoed area.	Unhoed area.
0	13.2	13.2
1	13.5	12.5
2	13.5	11.5
3	13.4	12.9
4	13.4	12.7
5	12.9	11.7
6	13.4	12.0
7	12.3	11.4
8	12.9	11.5
9	13.2	10.4

In this instance the hoed area retained just sufficient moisture so that the tea did not suffer from drought severely. In the unhoed area moisture fell to a point when the tea suffered. Of course one of the chief practical difficulties that arises in maintaining a soil mulch is the question of labour but on gardens where such a protection is essential every means should be adapted to this end. Bullock drawn cultivators, such as the spring toothed harrow, should be made as much use of as possible since one of these machines can cultivate a large area (2 acres) in a day and requires only one man and a boy to each machine and buffalo.

The depth of the cultivation is not of so much importance as the dustiness of it.

Shade trees.

The effect of shade trees has often been a subject of discussion for the effect varies considerably. In some gardens trees do have a beneficial effect in that bushes underneath them do not appear to feel the drought as much as those not under shade trees. On the other hand there are many instances where tea has died under shade but has not not done so away from trees. On sandy soils where the water level in the cold weather recedes to a considerable distance, and

in years of very severe drought the tea bushes under shade tree areas are likely to suffer because the deeper rooting shade trees prevent any water becoming available for the more shallow rooting tea. In such cases it is necessary to select shade trees that carry no leaves during the dry weather because evergreens only accentuate the trouble.

In the majority of instances, however, the shade tree does good and helps the tea bush to withstand the drought. In these instances the shortage of water in the soil is not the only factor. The effect of the shortage of water is undoubtedly to weaken the bush and it then is much more liable to disease attack; especially is this noticeable if the bush is exposed to the direct sunlight. In such instances the shortage of water in the soil is not so great as to cause the death of the bush but it is sufficient to prevent the bush from obtaining sufficient moisture to maintain itself in vigorous health. In such cases shade over the bushes is of marked benefit. In these instances it will be noticed that not all the bushes in an exposed area die and it is often noticed that whilst one bush may die the immediate neighbours appear to suffer but little. It is the weakly bush in such cases that has fallen a victim to some disease attack induced by the drought conditions. This perhaps is the most common effect of drought and the remedy is to strengthen the bushes by good treatment during the growing period. Shade during the dry hot weather is of considerable benefit and trees that carry leaves during this paticular season of the year are an advantage. Boga medeloa (*Tephrosia candida*) is of much value in such cases.

Pruning.

For protection against drought it is necessary to prevent the removal of water from the soil. Mulches on the soil surface do much to prevent loss of water, but there is another way in which soil water can be lost and that is by evaporation from the leaves of growing plants, either jungle or tea plants, and it is necessary to see that such leaf areas are reduced to a minimum.

The land must be kept clean of jungle but it is also necessary to remove as many leaves as possible from the tea bushes.

This is usually done by pruning. From this remark it might be deduced that all that was necessary would be to remove all leaves from the bushes when pruning, but this would not do, for the stems would then start to dry and disease would certainly attack the drying stems. It is necessary to leave a few leaves on the bushes and these leaves should be left as near the top of the stems as possible.

The best method is to prune so early that new leaves at the top of the stems on the one-year old wood are developed before the drought makes itself felt. The water available in the soil is generally sufficient for such a restricted leaf area and the growing leaves prevent the stems from drying and prevent the various diseases from seriously damaging the bushes. It is of importance to have healthy vigorous bushes. Pruning at any time and however lightly it may be done, weakens a bush.

A bush left entirely unpruned is less subject to the attacks of disease organisms but the water supply in the soil may be insufficient for so large a leaf area and consequently the bush will die back. This actual dying back is not of serious consequence for at the end of the drought the bush can be pruned just below the point to which the die back has occurred, but since the bush had at the early part of the dry weather a large leaf area, it will cause the available soil water to be used up more quickly and consequently on such areas the drought effect will be noticed earlier and will be felt over a longer period of time. In areas that suffer only from drought and which can be distinguished by all bushes suffering, more or less to a like extent, the pruning of the bushes before the drought is to be recommended.

NITROGENOUS MANURES.*

P. H. CARPENTER, F.I.C., F.C.S.

AND

H. R. COOPER, B.Sc., F.C.S.

Of all the plant foods which can be supplied to the soil as manure, nitrogen is of chief importance.

Abundance of available nitrogen in the soil causes good growth of stem and leaf. With crops grown for their fruit some caution has to be exercised in applying nitrogen, since excess may cause vigorous growth of leaf and stem, and retard the formation of flower and seed. Still, even for such crops, nitrogen is always an important ingredient of the manure mixture, since the plant must grow a big frame if it is to carry a big crop of seed. With tea we have no objection if the bush "runs to leaf," but quite the contrary, so that for tea manuring the provision of nitrogen is of even greater importance than for most other crops.

On soils with plenty of available nitrogen we find tea bushes with fine frames of good red wood, the "pruning wood" thickens up well, and the bush in the season looks dark and healthy and carries satisfactory flushes. There are many reasons for the production of hide-bound frames with thin shoots growing a little yellow leaf, but the commonest reason is a deficiency of available nitrogen in the soil.

Like any other good thing, nitrogen manuring may, of course, be carried to excess. When excess is used, quality is lost, and the tea becomes more liable to certain diseases. Used wisely to produce a bigger bush with more yielding shoots, not only need no quality be lost, but the temptation to make a crop

* This article should be read in conjunction with "Rotation of Manuring," Quarterly Journal, 1924, Part II.

by coarse plucking is reduced. With regard to disease also, only excess is to be feared. A bush getting sufficient nitrogen is healthier than a bush getting too little, and again a sufficiency of nitrogen produces flushes big enough to make over-plucking unnecessary.

Not only is the nitrogen the most important item of a manuring programme, but it is also the most costly.

Nitrogen may be obtained in many different forms, of different efficiencies and at greatly different prices. The selection of forms of nitrogen which will give the greatest efficiency for cost is therefore the point of first importance in devising a manuring programme.

The prices vary with the market but accurate information on this point can always be obtained. Accurate information on efficiency can only be obtained by actual experiment on the particular soil.

We have at Borbhetta a large number of different forms of nitrogen under experiment, and can make very fair guesses as to how far these results are likely to apply to other soils. We have also the advantage of the results of a certain number of trials conducted by managers on other soils. Even when no definite trial is made, the reports received from a number of managers on the way manures appear to have acted, are of value in the aggregate.

We have therefore a lot of evidence on which to judge the relative efficiencies of different manures, although it is impossible to give figures. That is, although we are not in a position to say that manure A is 50 per cent. more efficient than manure B, it is generally possible to say that Rs. 20 spent on manure A will give very much more increase in crop than Rs. 20 spent on manure B, in the case of the particular soil under discussion.

Nitrogenous manures are divided into two main classes :—

1. Organic manures.
2. Chemical, or readily soluble manures.

Organic Manures.—Common examples are oilcake, refuse fish or animal matter, and green manures.

All these contain forms of nitrogen insoluble in water, and since a plant can only take in nitrogen through its roots, insoluble nitrogen compounds must first be rendered soluble in the soil. The only soluble forms of nitrogen of any importance in the soil are ammonia and nitrates, and since ammonia is converted very rapidly in soil to nitrates we may say that in practice all forms of nitrogen must be first converted to nitrates before they are of any value to the plant.

This conversion takes place naturally in the soil under the influence of certain bacteria always present in normal fertile soils. The efficiency and rate of the conversion vary with different soils. The efficiency of the conversion is always small. In laboratory experiments with oilcake for example, we fail under the best conditions to get more than 70 per cent. of the total nitrogen converted into nitrates in the soil.

The rate of conversion of organic nitrogen into soluble nitrates is also of importance. On very heavy soils the rate is so slow that in practice the increased concentration of nitrates obtained at any one time may be too small to provide any considerable benefit to the bush. On light soils however the rate of conversion is relatively rapid so that organic manures are commonly very efficient on light soils. On very light soils organic manures are preferable to soluble manures, which are subject to over-rapid washing out, whereas the organic manure being insoluble remains in the soil and produces soluble nitrates for the use of the plant, at a rate nearer to that at which nitrates are absorbed by the plant.

In addition, nitrogenous manures act better when there is some decomposing organic matter in the soil so that on soils deficient in organic matter, better results are often obtained from organic than from readily soluble manures.

For these reasons there is a general preference for organic rather than chemical manures, and the organic manures there-

fore are more costly. Some additional cost is often justified by results, particularly on light soils.

Chemical Manures.—Of these, nitrate of soda provides nitrogen in the form in which it can be absorbed at once by the plant, and there is therefore no loss in conversion; but nitrates under heavy rain are lost fairly rapidly from the soil. Sulphate of ammonia is held by the soil well, but is converted fairly rapidly to nitrates when it becomes subject to washing. Nitrolim, on soils which suit it, is also converted rapidly into nitrates.

The use of these readily soluble manures is made possible on all soils by the fact that the greater value of small quantities of nitrogenous manure lies in the production of rapid growth of shoots during the spring when rainfall is not commonly very heavy. For this purpose the rapidity of action of soluble manures is of special importance, and this rapidity of action is also of advantage in giving a large part of the increase due to manuring early in the season when there is no difficulty in finding labour to deal with it.

On the whole with the small quantities commonly used in tea (about 30 lbs. nitrogen per acre) we are in favour of the use of the readily soluble forms of nitrogen except on very sandy soils.

The necessary organic matter may be added in greater quantity and very much more cheaply as cattle manure or green manure than as oilcake or animal meal. Our general policy then is to use cattle and green manures as the sources of organic matter, and to use the quick-acting and at present relatively cheap soluble chemical manures as the source of the additional nitrogen.

Unit Values.—Many materials supplying nitrogen are on the market as manure. These vary greatly in their prices and in their contents of nitrogen. The simplest way of comparing costs for the same quantity of nitrogen is to divide the cost per ton of a manure by the percentage of nitrogen it contains. This value $\frac{\text{Price per ton}}{\text{percentage of nitrogen}}$ is called "cost per unit of nitrogen" in the particular form.

Thus of two oilcakes—

No. 1 at Rs. 63 per ton containing 4½ per cent. nitrogen,
No. 2 at Rs. 75 per ton containing 5 per cent. nitrogen,
the unit cost of nitrogen in No. 1 is $\frac{63}{4\frac{1}{2}}$ = Rs. 14.
and in No. 2 is $\frac{75}{5}$ = Rs. 15.

Therefore oilcake No. 1 is a cheaper source of nitrogen than No. 2.

This method is very useful for rapid comparison of values. In the tables below are shown unit costs of nitrogen in all the common nitrogenous manures now on the market. Table I gives the common manures which are valued for their nitrogen content only.

TABLE I.

MANURES WHICH SUPPLY NITROGEN ONLY.

The prices given are of course not firm quotations and are subject to usual market fluctuations. They however serve as a good guide.

	Nitrogen per cent.	Price* per ton.	Cost per unit of nitrogen.
CHEMICAL MANURES.			
		Rs. As.	Rs. As.
Sulphate of ammonia	20	200 0	10 0
Nitrolim	19	230 0	12 3
Cyanamide	18	220 0	12 4
Nitrate of Soda	15	240 0	16 0
ORGANIC MANURES.†			
Steamed horn meal	12	200 0	16 11
Ground-nut cake	6½	108 8	16 11
Rape cake **	4½	80 8	17 14
Dried blood meal	11	210 0	19 1
Castor cake	5½	169 12	29 8

* Price in Calcutta, taken from "Capital" for August 28th, 1924, and from recent private quotations.

† The organic manures all supply in addition to nitrogen a little phosphoric acid and potash, but the amounts of these low priced ingredients are so small as to be practically negligible.

** Rape cake usually is obtainable at lower rates locally. At Rs. 2-8 per maund the unit cost of nitrogen in the normal quality (4½ per cent. nitrogen) is Rs. 15-9.

Many organic manures contain considerable quantities of phosphoric acid, and to some a little potash is added to complete a mixture which supplies all three important plant foods, nitrogen, phosphoric acid and potash. In this case an allowance must be made for the value of the phosphoric acid contained.

On the present market—

Potash is worth about ... Rs. 3 per unit.
Phosphoric acid is worth about ... Rs. 4 per unit.

If sterilized animal meal, quoted at Rs. 175 per ton contains—

7 per cent. nitrogen
7 per cent. phosphoric acid
5 per cent. potash.

Then the phosphoric acid in it is worth Rs. 4 by 7 = Rs. 28 p. ton.
and the potash ,, ,, Rs. 3 by 5 = Rs. 15 ,,
The potash and phosphoric acid together are worth Rs. 43 ,,

The value of the nitrogen in one ton of animal meal is Rs. 175—43=Rs. 132.

Then the price per unit of nitrogen is $\frac{132}{7}$ =Rs. 18-13.

In this way the unit cost of nitrogen in the mixed manures is calculated below :—

TABLE II.

Unit costs of nitrogen in mixed manures.

Manures.	Nitrogen per cent.	Phosphoric acid per cent.	Potash per cent.	Price per ton.	Cost of nitrogen in 1 ton.	Cost per unit of nitrogen.	
				Rs.	Rs.	Rs.	As.
Muscleox ...	10	5	...	120	100	10	0
Nervox	10	5	...	135	115	11	8
Sinox	10	10	...	140	100	10	0
Milled fish guano ...	7	9	...	140	104	14	13
Sardine guano ...	5	10	...	125	85	17	0
Sterilized animal Meal :—							
Ordinary ...	7	7	...	155	127	18	2
Special ...	7	7	2½	165	129-8	18	8
Acme ...	7	7	5	175	132	18	14

At present prices, the great variation in cost for the same quantity of nitrogen is very striking. We have however to consider not only the quantity of nitrogen added but the efficiency of the form in which it is added. A reference to Quarterly Journal, 1924, Part II, will show how different were the responses obtained from five different forms of nitrogen at Borbhetta. On those results, only one artificial manure is worth considering, and that is Nitrate of Soda. There is no doubt that this result accurately represents the action of the manures actually applied on the Borbhetta soil, but there are considerations which lead us to the opinion that these results are not of general application. First, the nitrate of soda supplies potash,* which none of the other plots received. Other experiments have shown that potash gives very marked results on this soil, and it is at least extremely probable that had the other plots also received potash, they would have given results more nearly equal to those from nitrate of soda. This would have increased the cost; but the mixture :—

150 lbs. sulphate of ammonia, costing	...	Rs. 13	6
40 ,, muriate of potash ,,	...	,, 2	6
Total	...	Rs. 15	12

could still be applied much more cheaply than 200 lbs. of nitrate of soda costing Rs. 21-7, while supplying the same quantity of nitrogen and at least as much potash.

Looking at the results from sulphate of ammonia one sees that the manure did well in two years out of the three in which it was applied. It is also doing very well indeed in 1924. In 1922 however it failed completely. 1922 was a fairly dry year and the failure may have been on that account. It is possible also that the failure might have been due to the presence of some accidental poisonous impurity, but unfortunately no sample remains on which this theory can be tested.

We have received several reports of similar failure of sulphate of ammonia, always from gardens on sandy soils. On

* This question was discussed in Quarterly Journal, 1921, Part I.

soils of reasonable clay content however we have had no reports of failure, but an enormous number of outstanding success. At its present very low price sulphate of ammonia can be recommended for most soils in spite of its comparative failure to date in the Borbhetta trials.

Similar considerations have to be applied to all other results obtained.

The notes below give our opinion after considering evidence from all sources to date, weight being allowed to results in other countries.

Sulphate of Ammonia.—A white or grey salt completely soluble in water.

It contains all its nitrogen as ammonia which is converted to nitrate in the soil very rapidly, and nearly always with very little loss in conversion. It is therefore almost exactly equal to nitrate of soda in rapidity of action, and on most soils, has proved to be about equally efficient as a source of nitrogen.

Sulphate of ammonia is very strongly acid, and greatly increases the soil acidity. On some soils which are insufficiently acid for tea (as many of the less fertile tea soils are) this property adds to the value of sulphate of ammonia as manure; but on soils already of high acidity the continued use of sulphate of ammonia will probably do harm, unless lime also is used occasionally. The increased acidity has not yet done any harm at Borbhetta after four applications each of 150 lbs. per acre.

This manure occasionally fails on sandy soils, but appears practically always to be successful on medium to stiff soils, and on clay soils often does well when no other source of nitrogen is successful.

The bulk of the supply on the market is a by-product from gas-works, and may contain undesirable impurities. It should be guaranteed free, for example, from more than a trace of cyanogen compounds which are poisonous. The small quantity of free sulphuric acid usually present does no measurable harm on

most soils, but is objectionable since it is this free acid which destroys the bags so rapidly.

A pure sulphate of ammonia is now on the market under the name "neutral sulphate of ammonia." This contains neither free acid nor cyanogen compounds and is therefore safe. Its present extra cost (about 25 per cent. increase) makes it hardly worth using, as compared with a *good* sample of the gas-works product.

Cyanamide and Nitrolim.—When nitrogen from the air is passed over calcium carbide at the temperature of the electric furnace, a substance called "calcium cyanamide" is formed. "Nitrolim" is the registered name for a particular maker's brand of this substance. The quality of different preparations may vary considerably, but we have no data upon which we can express an opinion about the merits of the preparations now on the market.

Calcium cyanamide, in soils which suit it, changes fairly rapidly into urea and then into nitrates. On some soils however the change does not go smoothly in this direction, but substances actually poisonous to plants may be formed. In trials this manure has generally done very well on fairly heavy loams, but at Borbhetta and on other sandy soils it appears to have had only a small good effect. As its unit price is higher, it would not generally be used in preference to sulphate of ammonia.

Sulphate of ammonia however is strongly acid and cannot be used indefinitely unless lime is used also. Cyanamide on the other hand contains free lime; a maund of cyanamide is roughly equal to a maund of crushed limestone. One can therefore often use cyanamide alone more cheaply than sulphate of ammonia and lime together.

Cyanamide has often been found much more effective when used together with a phosphatic manure than when used alone.

Soils which should do well with cyanamide or nitrolim are the heavier (but not the sandy) red teelas of the Surma Valley, the medium to heavy red loams of Golaghat, Dooars red bank

soils, the reddish loams of Upper Assam and soils similar to them.

Nitrate of soda.—This is a white, or when slightly impure, pinkish or grey salt completely soluble in water.

It contains all its nitrogen as nitrate, the form of nitrogen immediately available to plants as soluble food. There is therefore no loss in conversion as with other manures, and the manure comes into action at once. It acts well on all soils, and there is no fear of occasional failure as with sulphate of ammonia or nitrolim.

The manure is very easily soluble in water, and is very little held by the soil. It cannot be recommended for very open soils on account of the readiness with which it is washed out.

On soils containing free carbonate of lime (as most British soils do) the use of nitrate of soda leads to formation of some carbonate of soda, which increases the soluble alkali in the soil and tends to cause clay soils to puddle. On the acid clays of North-East India no such evil need be feared. Four applications, each of 200 lbs. per acre, at Borbhetta, so far from developing alkalinity, have actually increased the acidity of the soil slightly. Nitrate of soda has done well on clay tea soils.

The impure nitrate of soda supplied as manure contains a little potash, and in addition renders potash from the soil soluble. It therefore acts not only as a source of nitrogen, but as a potash manure also, for several applications at least.

It is, at present, relatively rather expensive, but has uses, for example where very certain and very rapid action is required as it is in the case of weak bushes, particularly if they are cut back. It is also useful for application late in the season in admixture with a potash manure, on diseased tea which requires stimulation to new growth; and on nurseries the growth of which is not considered satisfactory by May or June.

Horn Meal.—This has not been tried as a tea manure alone, but is a common constituent of animal meals. In Europe it is

slow in action, and the organic matter it supplies is of little value from the point of view of soil condition.

It appears therefore to offer poor value at the price quoted.

Rape Cake.—Except for cattle manure, rape cake has been in use longer and on a much bigger scale than any other manure for tea. It is therefore well understood and is generally in favour.

It is not very rapid in action except on very sandy soils, and on heavy soils it is very slow. It is not therefore very suitable either for cut back or for unpruned tea when rapid action is essential. On top pruned tea however it generally does well. Its cost in Calcutta is at present high, but it often may be obtained at a fair price locally. Compared with sulphate of ammonia at Rs. 200 per ton, it is worth only about Rs. 1-10 per maund on account of its nitrogen content; but since it supplies also a little potash and phosphoric acid and some organic matter it is probably worth while to pay up to about Rs. 2 for medium soils. On very coarse sands where chemical manures are undesirable one may be forced to pay up to Rs. 2-8, if no alternative offers, but the price per unit of nitrogen is then Rs. 15-9 per unit and as will be seen from the table one can buy fish manure a little cheaper than that, if the phosphoric acid supplied by the fish is required.

Cost can be averaged down by using a mixture. For example—

4 mds. oilcake at Rs. 2-8 per md.
and 1 md. sulphate of ammonia at Rs. 7 „ „

would make a very useful mixture to supply nitrogen even to a very sandy soil.

Ground-nut Cake.—We have no knowledge of trials of this manure. It has always been too expensive. At present however it compares well with other organic manures available in Calcutta. It is probably much the same in action as rape cake.

Castor Cake.—It is rather more rapid in action and efficient than rape cake. At present it is hopelessly dear, which is rather

surprising since it is not used as catlte-food as the other oil-cakes are.

Sanos Oil-cake.—The Sanos oilcake is a proprietary mixture of oil-cake with a little nitrate of potash. This admixture probably makes it more rapid in action and more efficient, but the present cost is very high.

Dried Blood.—During the war when export was impossible this manure was relatively cheap and was often used. It was found to be rather more efficient than oil-cake. At present it is too expensive.

The mixed manures shown in Table II, all supply phosphoric acid in addition to nitrogen, and some supply potash also.

In the Rotation of manuring given in Quarterly Journal, 1924, Part II, the cheap "specimen rotation" depended partly for its cheapness on the use of ground mineral phosphates, and the efficiency of the rotation was considered to be increased by the use of phosphoric acid in large quantities in those years when green crops are sown, rather than adding a little each year together with the mixture of artificials.

A few soils also require no phosphoric acid, in which case it is pure waste to pay more for a nitrogenous manure because it contains phosphoric acid.

The use of these natural mixtures therefore somewhat restricts our freedom of action in making up a programme of manuring since we cannot add nitrogen without adding phosphoric acid with it. When however the phosphoric acid is required, very useful mixtures can be made up with these manures, and for this purpose the "cost per unit of nitrogen" shown in the last column of Table II, compares accurately with the relative costs at the prices quoted.

Muscleox, Nervox Nitrox.—These are manures made up of animal refuse which cannot be made sufficiently small to go into animal meal. They consist mainly of sinews (with pieces of adhering bone), and of pieces of the hide.

Trials at Borbhetta on this kind of material have shown practically no result whatever up to the end of four years, but are beginning to show a little good effect after that time. It is probable that all soils do not show the same lack of power to digest this kind of material. On heavy soils rich in humus this material has been used for many years with an apparent success which satisfies the users. However, such coarse material must always be extremely slow in action, and that means also that it cannot be very efficient. Reference to the tables will show that these materials cost as much per unit as sulphate of ammonia.

Sinox.—Sinox is similar to the above three but contains also large pieces of bone to bring up its phosphoric acid content.

The sinew-manure, used in the Borbhetta trials, was as finely divided as the nature of the material allows.

The manures supplied to gardens under some of the above names are generally composed of pieces very much too big, which lowers efficiency still further. Pieces of skin several square feet in area, the complete tail of a cow, and a portion of a cow's leg (with the hoof!) have been reported as being supplied in consignments. Such things no doubt are exceptional, but such occurrences indicate that no great care is taken to secure even a moderately good state of division.

Milled Fish Guano—consists partly of dried fish broken into coarse meal, and partly fish offal (from canneries) also made into meal. The offal is mainly bones and scales which provide manure less rapid in action than dried meat. However, milled fish guano is a manure which generally does very well indeed, even on relatively heavy soils, and with the exception of the last mentioned mixtures of sinew and skin this is at present the cheapest purely organic manure on the Calcutta market and is therefore being widely used.

Sardine Guano.—The price quoted for this form of fish manure is very high per unit of nitrogen, although sold at a lower price per ton. This fact becomes plain if the costs per

unit on Table II are compared. Not only is it more expensive, but the manure supplied is usually much less suitable since it contains whole fish impossible to incorporate evenly with the soil and too big for reasonably rapid action. The whole fish, moreover, are too attractive to dogs and jackals, and even to some coolies who become ill from eating the stuff.

Sterilized Animal Meal.—After oilcake, animal meal probably has been more widely used than any other single manure in the tea districts. Since it supplies sufficient phosphoric acid in addition to nitrogen it is for most soils superior to oilcake used alone. The practice of adding nitrate of potash to make the Acme Mixture not only made this a complete manure by the addition of potash, but increased its rapidity of action also. It thus deserved to become, and has become, a firm favourite among planters. The original sterilized animal meal consisted of all those parts of carcasses which after treatment with superheated steam could be reduced to a good meal. It consisted mainly of meat meal and fine bone meals, the nitrogen content being brought up by the addition of a little horn and hoof meal.

The prices quoted in Table II refer to this material, which is still in the market. It will be seen from this table that it is at present very expensive, and its efficiency compared with that of mixtures, which can be made up from cheaper materials, does not warrant this very high price.

There are also on the market other mixtures under the same name.

Thus a mixture of steamed horn and bone meals could be made to sell at Rs. 16 per unit, and could quite fairly be described as sterilized animal meal, but its efficiency would not be that of the original animal meal. The attempt to meet the demand for the old favourite animal meal has led however to the placing of mixtures of many kinds on the market. "Animal Meals" have come to our notice containing fish and oilcake, and in fact there has been no bar to applying the name to any mixture whatever. In one case the nitrogen contained in a mixture called animal meal was nearly all sulphate of ammonia.

Such a practice is particularly objectionable. When it is decided to pay a high price for a particular organic form of nitrogen because that is thought more suitable for the soil, care should be taken to see that the cheapest, and one of the most soluble manures (sulphate of ammonia), is not supplied under another name.

Summary.

(1) The nitrogenous manure is the most important item of a manuring programme.

(2) While the organic matter content of the soil should be kept up by means of cattle manure and green crops, the manure purchased in Calcutta may be as a soluble chemical manure which is both rapid in action and cheap.

(3) Sulphate of ammonia, at present prices, offers the best value as a nitrogenous manure for most soils. Cases where others are more suitable are discussed.

(4) Where an organic manure is specially desired, milled fish manure at present offers best value, in cases where phosphoric acid is required at the same time. When nitrogen only is required then the oilcake which provides the cheapest unit of nitrogen must be chosen.